Tappi

PUBLISHED BY THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

FEBRUARY 1955

VOLUME 38 · NUMBER 2

JOSEPH HORNE CO.

ad-about-town travels in good company

Many successful retailers, like the Joseph Horne Company, have learned the value of selecting a color for their wrappings that is all their own. This distinctive color represents them all over town — makes everything they sell a traveling advertisement.

Why not sell *your* prospects in the retail field on the idea of adopting a "store color"— and help them in their selection. You can offer them a wide range of shades to choose from. See how it helps you get new business . . . steady repeat sales, too!

Should you need help in developing a color or selecting the proper dye, get technical assistance simply by writing E. I. du Pont de Nemours & Co. (Inc.), Dyes and Chemicals Division, Wilmington 98, Delaware.

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FOR MAXIMUM SOLUBILITY *Du Pont acid dyes*

FOR MAXIMUM LIGHT FASTNESS

Du Pont dispersed organic pigments: "MONASTRAL" Fast Blues, "MONASTRAL"* Fast Greens, "LITHOSOL"* Pigments*

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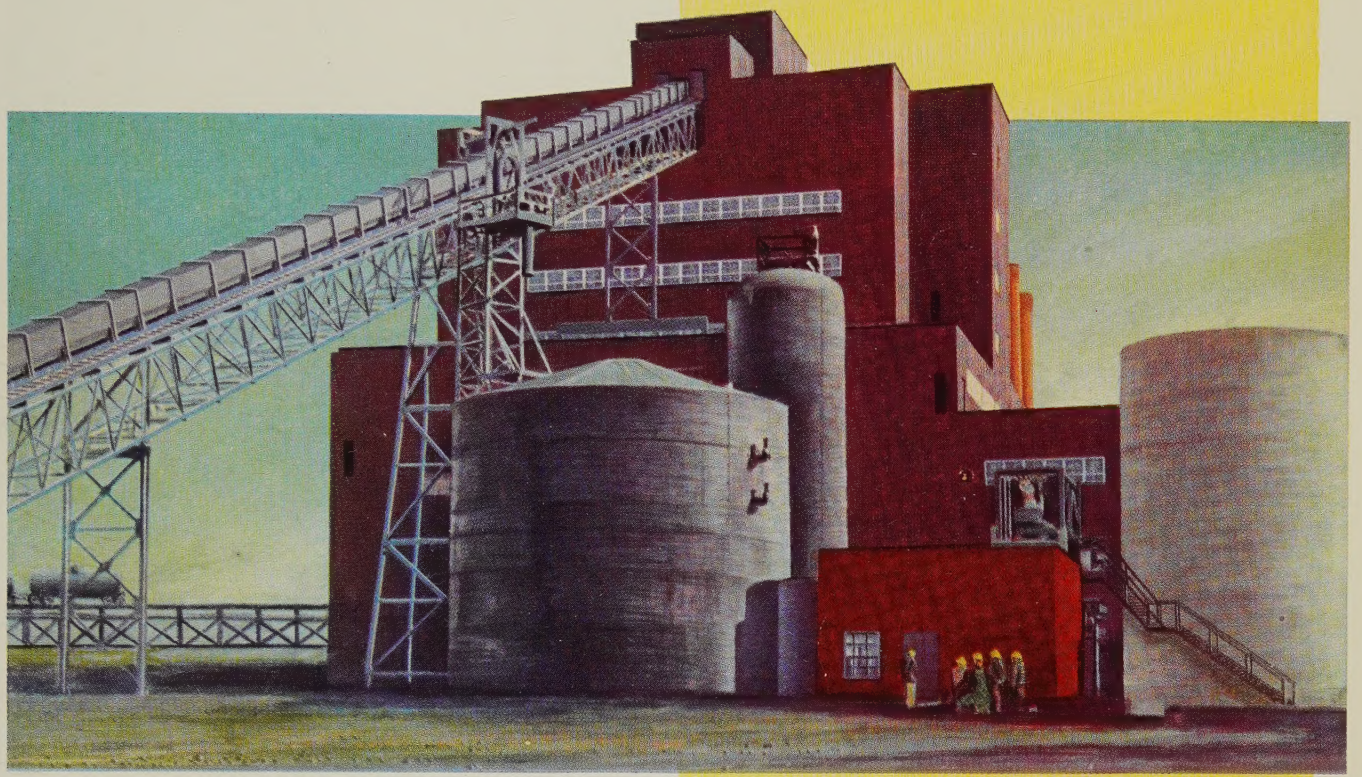
BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

Du Pont Dyes

NEW PROCESS FOR PULPING HARDWOODS



In Maine's northern Penobscot region, hardwoods are available for paper pulp in plentiful supply.

When Great Northern Paper Company expanded its mill at East Millinocket, Stone & Webster Engineering Corporation was engaged to engineer and design the Company's almost completely automatic Chemi-Groundwood Pulp Mill—the first large commercial chemical plant of its type for removing the resins and lignins in hardwood.

Utilizing information obtained from the client's pilot plant operation, the Chemi-Groundwood Pulp Mill employs pioneer developments and radical departures from accepted practice in the pulp and paper industry.

At Great Northern Paper Company's new Chemi-Groundwood Pulp Mill, hardwood logs are loaded automatically into digesters, cooked in recirculating liquor, dropped into water pools for cooling, leaching and storage, conveyed through a stream barker and thence to grinder. The self-contained mill has its own cooking liquor preparation plant, chemical handling and storage facilities.

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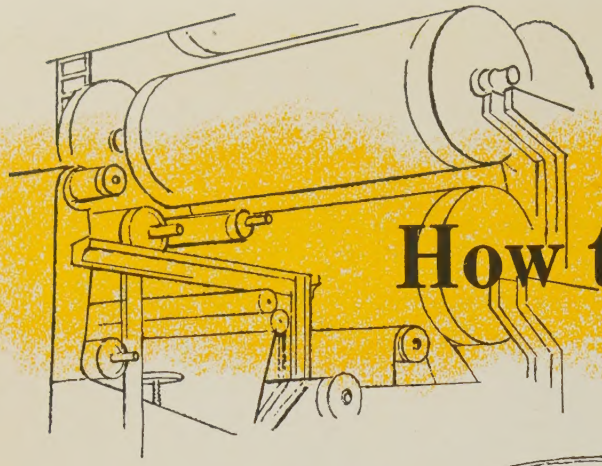

How this Paper Mill made *ONE* drum of defoamer do the work of *TWO*

The efforts of the Nopco technical service men do not always stop with supplying effective defoamers at competitive prices. Very often their wide experience with all types of pulp and paper mills can suggest money-saving ways of using these defoamers.

☆ ☆ ☆

In one well known mill, for instance, the Nopco technical man was able to bring about important savings with his practical suggestions for improving both the handling and distributing of the defoamer to the points of use.

The result: at the year's end this mill found they had cut their defoamer consumption exactly in half, at a clear saving of $6000 a year!

Nopco, pioneer in paper chemicals, knows well that paper and pulp mills vary so widely in their operating conditions that no one defoamer will work equally well for all. By proper selection from our Nopco KF* Series of paste defoamers, or our Nopco LD* Series of liquid defoamers, we are confident there is one defoamer which will produce foam-free paper at high speeds for *your* mill. Why not give the Nopco paper specialist the chance to study your operation carefully and make recommendations? His experience may quite possibly show you an extra saving like the one cited here.

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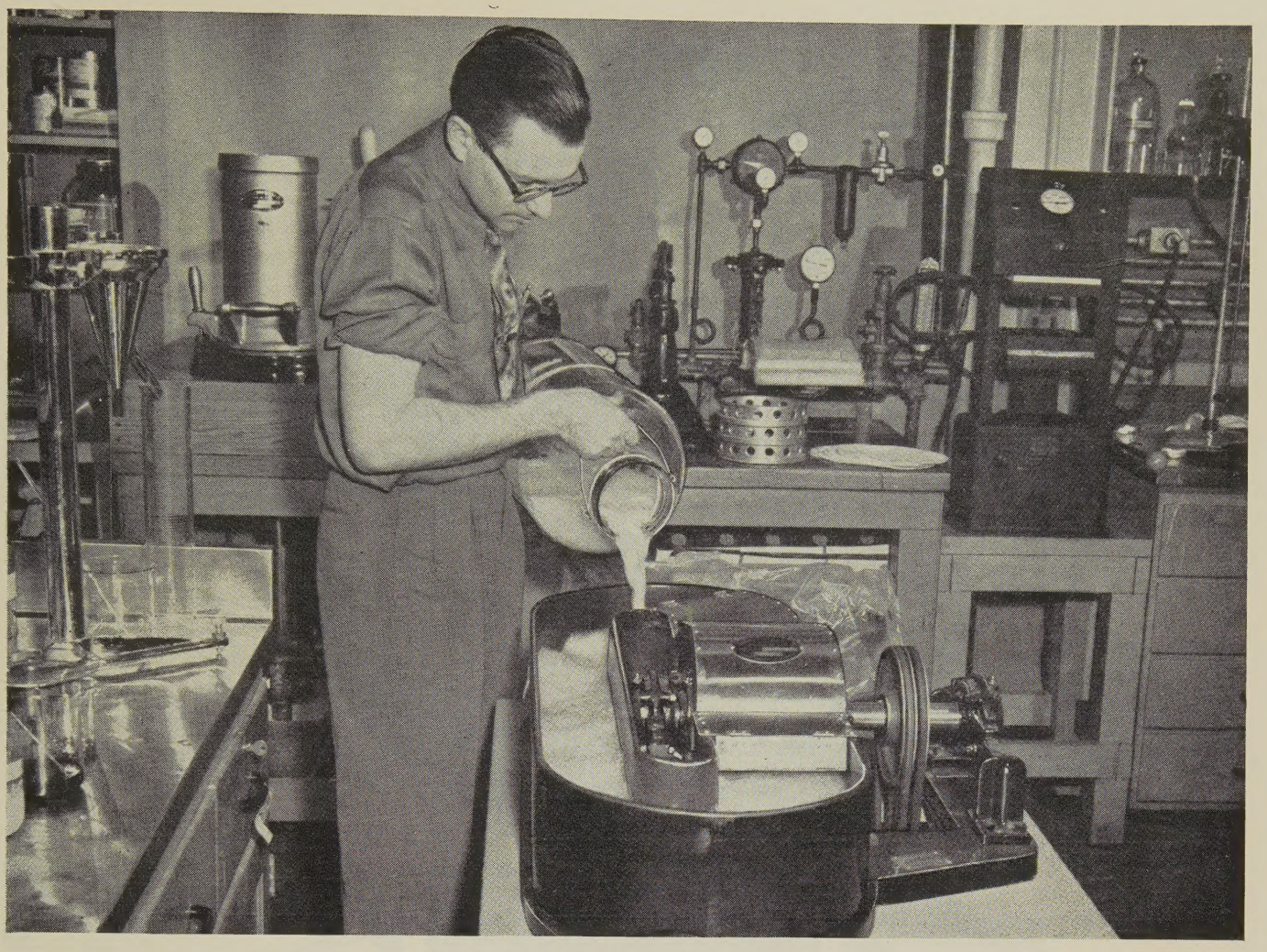

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in improving paper with CHEMIGUM LATEX

CHEMIGUM LATEX offers many opportunities to improve many types of paper in many forms. To help you find those which apply to your product, the Goodyear Chemical Division has established a new and separate laboratory, fully equipped and staffed with experienced personnel.

CHEMIGUM LATEX is an aqueous dispersion of a butadiene-acrylonitrile copolymer. It is especially suited to the beater-impregnation of Kraft or other pulps for outstanding toughness, improved feel and drape, better bending and folding plus unusual resistance to oils or greases, with no need for sensitizing or special equipment.

CHEMIGUM LATEX, because of its permanence, flexibility and binding properties, also is used in coatings, adhesives and inks that do a better job longer. What can you do with it? Qualified technical assistance is available by writing to:

Goodyear, Chemical Division, Akron 16, Ohio

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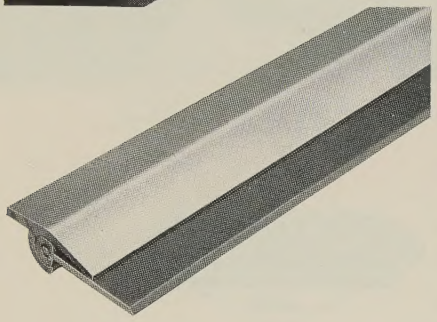
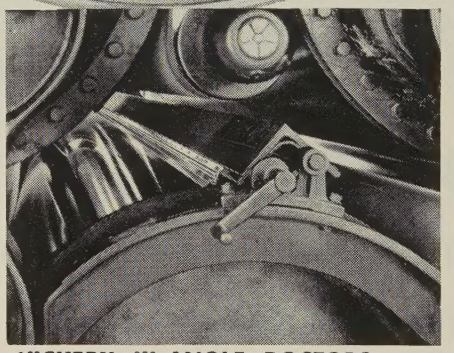
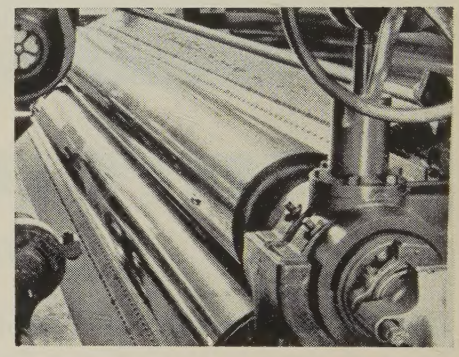


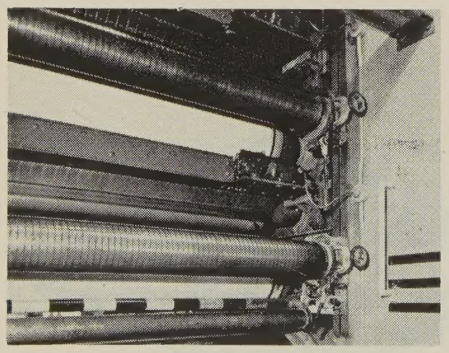
VICKERY "RS" DOCTORS are ideal for those places where blades used to stick or space for blade changes was cramped. They assure quick, easy insertion and removal of the blade. They're proving enormously popular. Close to a hundred mills have adopted them already.



VICKERY HI-ANGLE DOCTORS combine light but firm blade pressure with extraordinary cleaning efficiency. They are *leak-proof*. Blades last longer.



VICKERY HI-FLEX DOCTORS have the two-way, super-flexibility that assures perfect blade contact and precise, frictionless pressure on every inch of calender and super-calender rolls.



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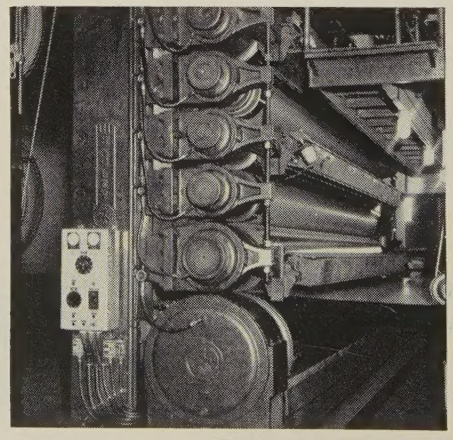

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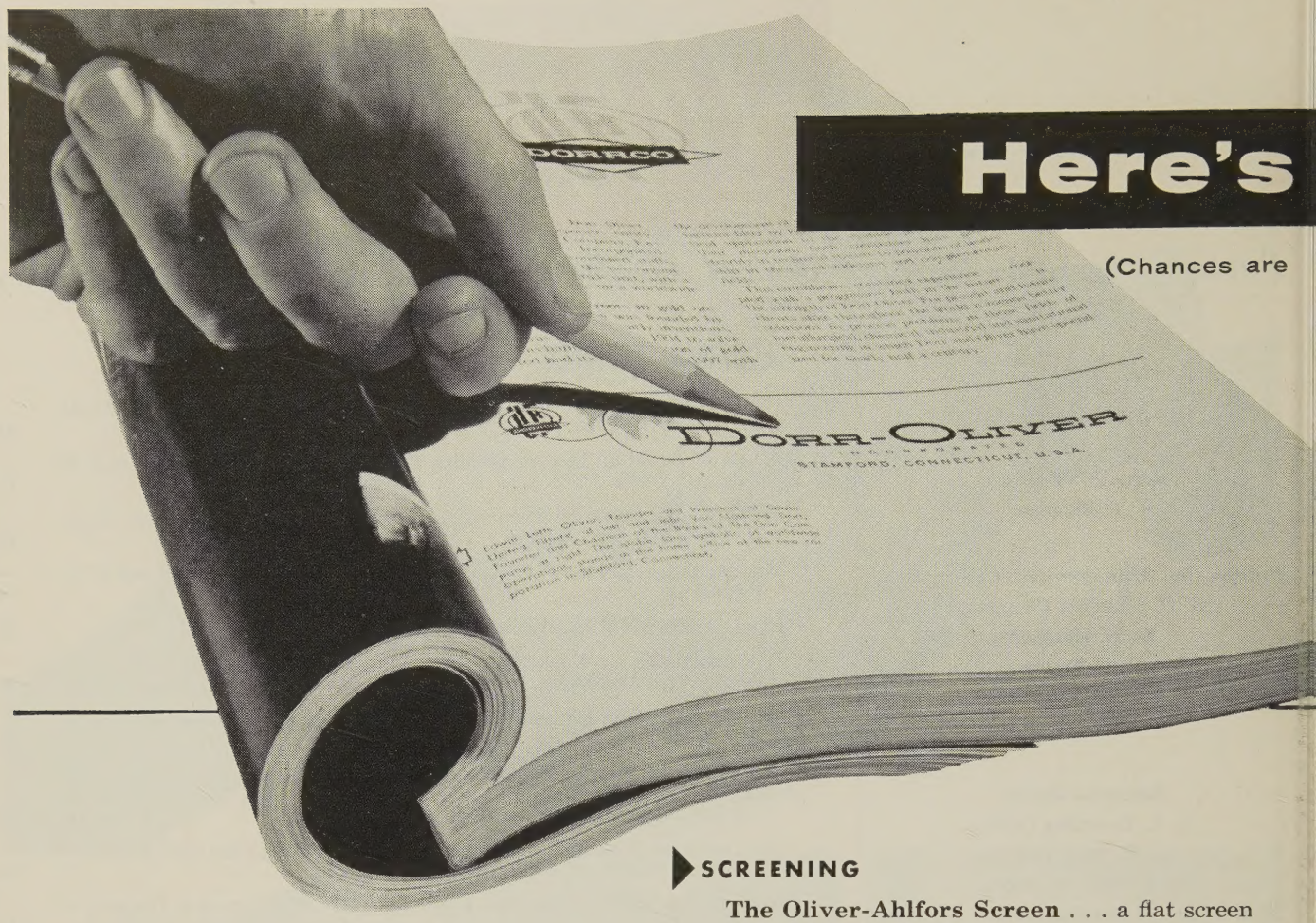

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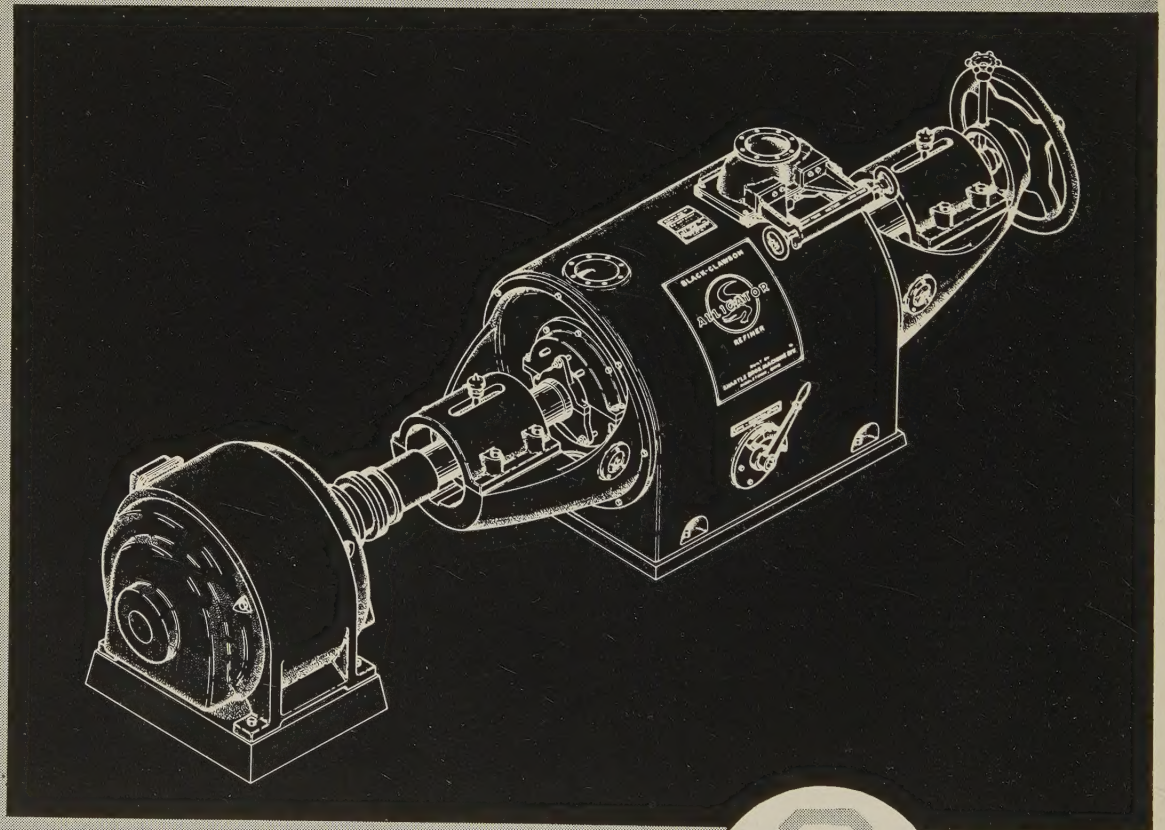

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Sulphite Pulp Acid Pumps Valves Digester Pumps and Valves	#640 Plastic with end rings of #379 Flexible Metallic #2012 Chempac®	#640 Plastic with end rings of #379 Flexible Metallic #2012 Chempac	#640 Plastic with end rings of #379 Flexible Metallic #2012 Chempac	#640 Plastic with end rings of #379 Flexible Metallic #2012 Chempac
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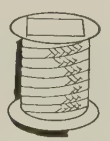

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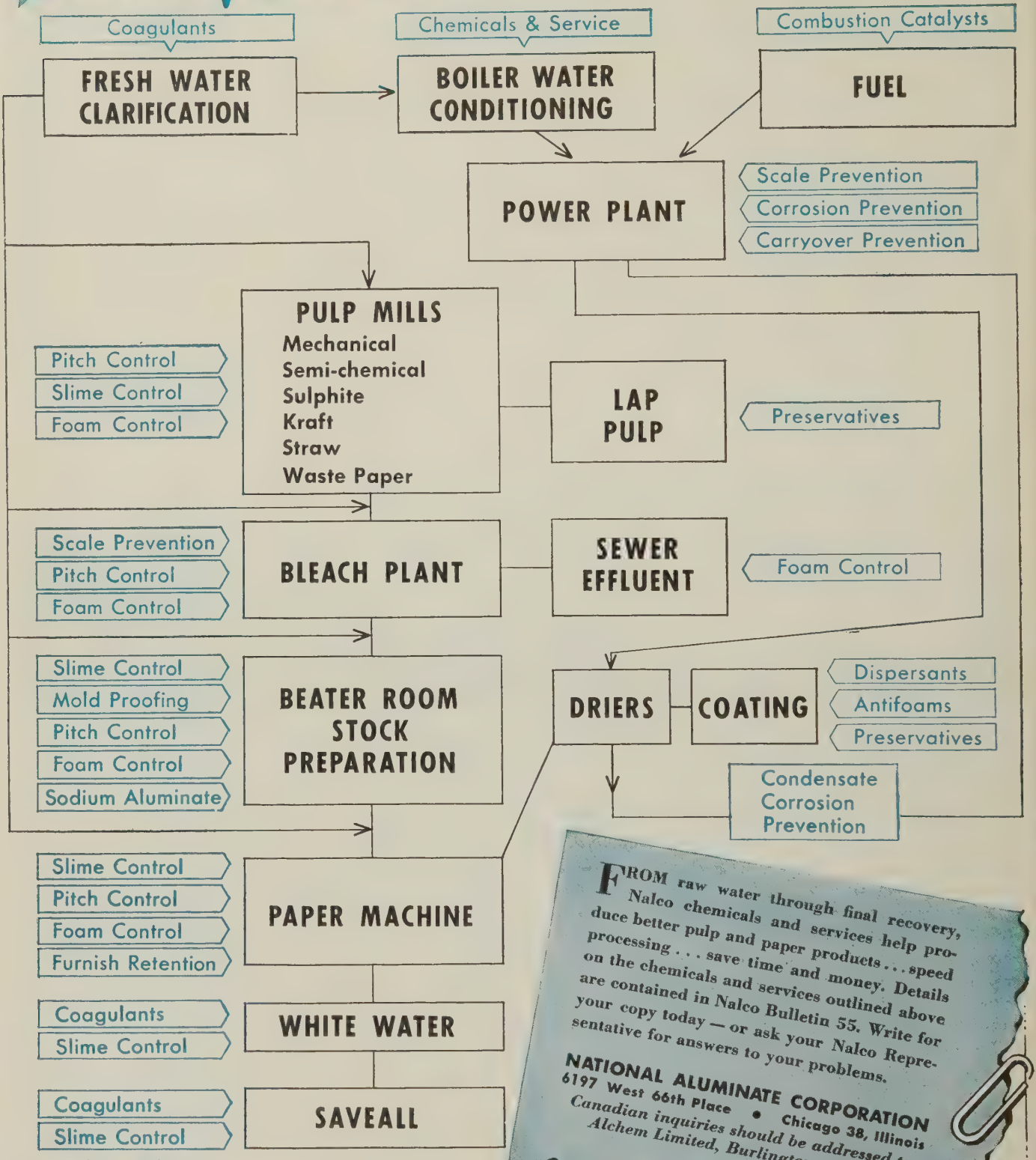

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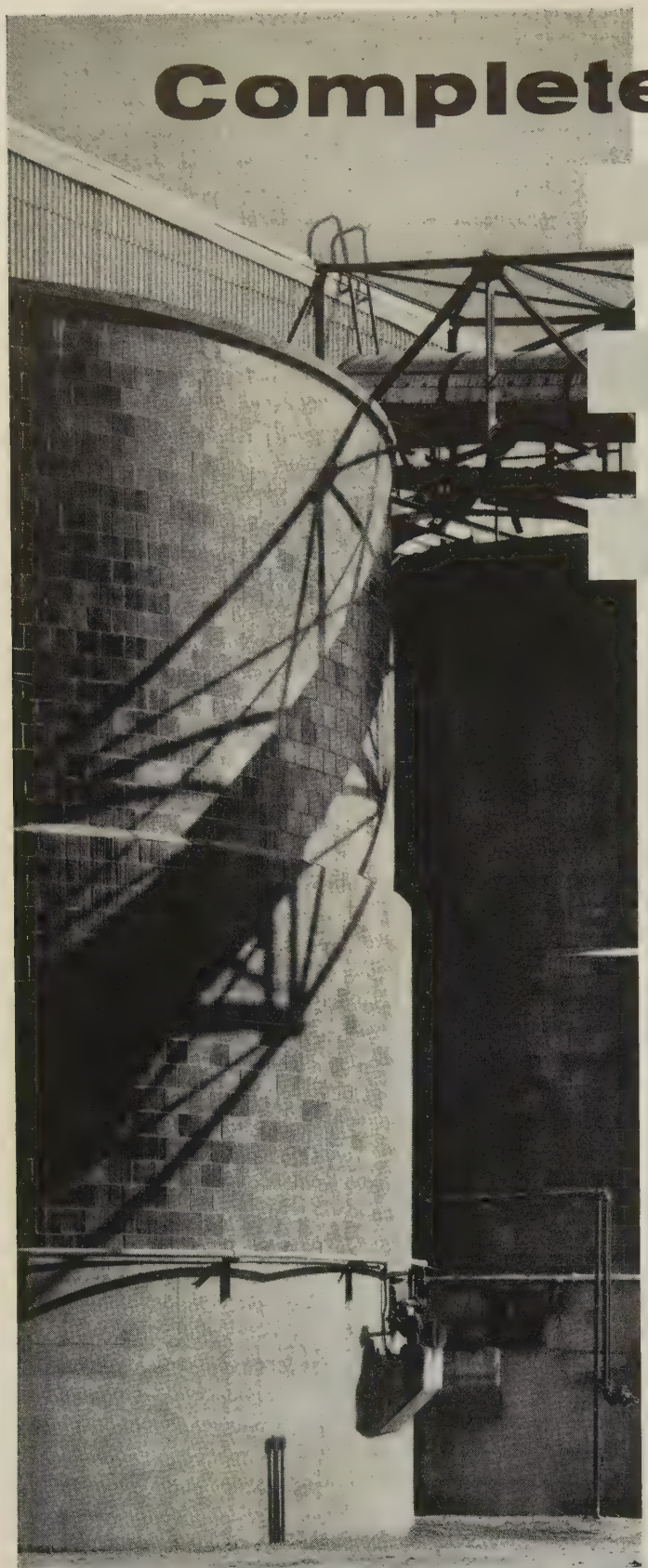

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REPORTS AND DISCUSSIONS

Presented at the National and Regional Conference

Condensations of Annual Meeting Papers

THE following are condensations of a number of papers to be presented at the 40th Annual Meeting of the Technical Association of the Pulp and Paper Industry, New York, N. Y., Feb. 21–24, 1955. The papers will be published in full in subsequent issues of *Tappi*.

Special Research Facilities at the Lowell Technological Institute, JOHN LEWIS

The paper is presented in two parts. The first part deals with the progress of the Paper Engineering Department over its first 5 years of existence. The second part describes several of the special facilities available in the Institute for sponsored industrial research through the Lowell Technological Institute Research Foundation.

The Paper Engineering Department became official in 1949 when Geoffrey Broughton became the first head of department after letters of inquiry from the officials of the school to the paper industry indicated that paper-trained graduates were needed. A well-equipped, new building was subsequently provided by the Legislature of the Commonwealth of Massachusetts. It was occupied in 1952.

The curriculum which has a chemical engineering background and emphasis on paper and board making and converting has graduated eleven students. The enrollment has grown to its present 71 students.

Attention is now being given to the M.S. graduate study program since the undergraduate, evening school, and summer school programs have been well established.

Industrial advisory committees have been formed for advice in general policy, equipment, guest lecturer, library, practical work and research problems. Scholarships have been established in the Paper Engineering Department by several industrial concerns and organizations.

The Lowell Technological Institute Research Foundation has been established by the Massachusetts State Legislature to coordinate and administer all sponsored research at the Institute. Through this organization the combined fiber experience of the paper, leather, textile manufacturing, textile engineering, textile chemistry, plastics and electronic engineering departments, and permanent personnel of the Foundation may be combined to solve any applicable paper problems which industry and government organizations are invited to bring to the Institute.

A New, Dry Felting Process for Making Tissues, Batts, and Boards, BROR E. ANDERSON and JAMES D'A. CLARK

As a result of successful development over the past few years, a simple, practical dry felting process has emerged for laying down and binding together fibers for making a wide variety of specialty papers, nonwoven fabrics, and matrices, from gossamer webs to heavy batts. The process incorporates three new principles: first, a "shower head" effect in the depositing heads. This provides a controlled restriction to the flow of the circulating air and fibers from the heads and assures uniformity of fiber deposition. Second, extremely low concentration of the fibers in the air used as the carrying fluid. Just as if the same concentration could be used in papermaking, this assures good formation even with fibers $^1/_2$ in. or more in length. Third, arranging that the moving stream of airborne fibers in the felting zone between the depositing head and the collecting screen is open to the atmosphere. This easily and simply allows the use of any number of felting heads in series. Since each head may deposit the same or a different mixture of fibers, this permits good production rates and an unusually wide versatility for the manufacture of various felted products. Solid or liquid binders may be applied to the structure in several different ways: for example, added to the fibers before they enter a head, to the air-fiber stream leaving a head, or to the partially or wholly deposited web. Almost any fibers may be successfully handled, provided they are neither so long and thin, nor long and crimped, as to readily form aggregates which cannot be kept dispersed by the fine, high-pressure air jets employed in the heads for that purpose.

Cleaning Deinked Stocks with the Bauer Centri-Cleaner, J. L. CLOUSE

A record is given of the commercial results obtained by the use of Bauer Centri-Cleaners on deinked stocks intended for use in high-quality bleached grades of paper. This included information on dirt removal by percentage and type, reject losses (filler and fiber), pumping pressures and economies achieved by replacement of usual process equipment. Particular attention is given to the removal of ink balls, adhesives, and other light types of impurities.

Use of Paper Stock, HENRY J. PERRY

Comparison of paper stock grades, past and present, is made with special attention to sources of major contamination.

The methods for correction of these problems by practical and economic means, as used by the Waste Paper Utilization Council, are outlined.

The need for review of current paper stock processing methods, and the need for new methods, is discussed.

Application of the Oliver-Ahlfors Screen to Deinked Stock, A. C. SMITH and FRED SCHORKEN

This paper reviews the installation and operation of two Oliver-Ahlfors screens at Newton Falls Paper Mill Inc., Newton Falls, N. Y., for screening 50 to 75 air-dry tons per day of deinked ledger, book, tabulating, magazines, and old papers prior to bleaching. Evidence of the satisfaction of the operation is indicated in the recent addition of a third screen.

The Newton Falls installation illustrates the new approach to pulp screening by the "upflow" principle, particularly as applied deinked stock.

The Oliver-Ahlfors consists of a screen vat with plates on top and a mechanically agitated diaphragm as the bottom member supported by a cast aluminum diaphragm plate. The pulp at 0.8 to 1.2% consistency is fed into this vat under constant, uniform head and flow is upward through the four 0.012-in. cut plates per screen. Plates are always submerged, eliminating "dry plates" and overcoming excessive dilution as on conventional flat screens.

Dirt, scale, bark, and oversize particles remain in suspension in the vat and are discharged through the adjustable reject outlet. Accepted fiber overflows the end of the screen at 0.6 to 0.8% consistency, while rejects averaging $5^1/_2$% of input to the screen have approximately 1% consistency.

The new screen installation reduced floor space requirements from 800 to 510 sq. ft. Uniformity of screen product has been improved, offering a cleaner, dryer screen room as screens and automatic plate cleaning shower are completely enclosed. A magnetic trap and string catcher are being installed to reduce the wire staples and number of fibrous strings which now necessitate periodic manual cleaning of the vat.

The Sulzer System of Water Extraction for Paper Machines, ROBERT THOMANN

The use of turbo-blowers instead of the conventional volumetric pumps for aspirating air from paper machines has been made possible by the development of effective separators for air-and-water mixtures. Turbo-blowers have many advantages for this application. Multistage units can be used for central aspiration from all the suction points of the paper machine. Power requirements are lower than those of liquid-ring pumps, and the work of compression can be utilized in the form of heat. As the blower characteristic is fairly flat, the pressure and suction quantity are automatically adapted to prevailing conditions. Drive is by electric motor through step-up gearing, or else by steam turbine, which allows of interesting combinations, especially in large mills. While the layout of the blower plant requires wide experience and careful study, all installations so far in service have attained in full the good results expected of them.

Graphical Determination of Roll Deflections, R. C. STURKEN and D. A. VERNER

A simplified and time-saving method of calculating deflections of rolls under load has been developed. This method involves the combining of the known formulas for beam deflections and moments of inertia of roll cross sections, and plotting the resulting

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equations graphically. By evaluating the ratios of lengths to diameter, inside to outside diameter, and journal length to roll length of a given roll, the deflection can be determined from these graphs. In addition, a nomographic chart has been prepared correlating all of the variables affecting the deflection of rolls under uniform load.

Development of the Shartle Alligator Refiner, H. P. Espenmiller

A new type refiner called the "Alligator" will soon be introduced to the pulp and paper industry. During the past several months, development work has been carried out employing closely controlled pilot plant precedures. This paper, for the most part, will present the results of these investigations.

The Alligator may be generally described as a conical refining engine since the fillings are of conical design. Beyond this, there is little similarity in filling design, method of stock treatment, and refiner operation, with standard bar-type conical refiners. Refining results from stock passing through a perforated rotating element, having holes approximately 3/8-in. diam. into the refining zone between rotor and stator. The stator is also perforated, having 1/8-in. holes about 1 in. long. In the refining area stock flow is divided. Part of the stock discharges into the long fiber chamber at the large end of the unit. Stock also is forced, by ram-like pressures produced by the rotor, through the 1/8-in. holes in the stator into the short fiber chamber outside the shell. Both stocks are discharged through a mix valve, permitting the withdrawal of various percentages as desired. Also both stocks can be recirculated to the inlet through internal channels, for multipass treatment.

An intensive study is being carried out in our stock preparation pilot plant to determine the operating and stock refining characteristics of the Alligator. A considerable amount of work has been accomplished and the portion that has been completed and analyzed is presented.

The refining variables of speed, power, put-through rate, consistency, and type of pulp have been studied. Also the Alligator has been compared, under ideal testing conditions, with standard bar-type conical refiners. Furnishes used include both hardwood and softwood chemical pulps, including semichemical.

The results obtained to date have been very interesting. The Alligator has shown power savings as high as 67%. Stock quality is not impaired but improved. On the basis of strength versus freeness, Alligator strength is generally higher. The results have shown the Alligator to be particularly adaptable for refining hardwood pulps such as kraft, soda, and semichemical. Excellent results have also been obtained on softwood chemical pulp.

In the majority of the tests conducted on all furnishes, the Alligator has exhibited the following characteristics:

1. It does not cut the fiber. The degree of fiber length reduction is very mild.
2. Freeness reduction is rapid and without cutting. This indicates good fiber wetting without fiber damage.
3. Higher tearing strength is maintained but at the same time bursting strength and tensile are also high.
4. Folding strength is always considerably higher.
5. Photomicrographs show excellent fibrillation even on the short fibered hardwood pulps.
6. Hydraulic efficiency is improved making available a greater percentage of the power expended for fiber treatment.
7. Refiner control presents no operator difficulties and permits a wide range of stock preparation controls.

Variables Affecting the Brightness of White Lined Paperboard, W. R. Csellak

Among the variables affecting the brightness of white lined paperboard are the brightness of top and inner (under) liner, opacity of top and inner liner, and the formation of top and inner liner. These variables are further affected by the type of furnish, degree of hydration, amount of liners used, type of white water system, cleanliness of felts, couching and wet pressing, drying, and calendering.

A process brightness loss of 8.0 on a top liner having an unrefined pulp furnish brightness of 75.0 was observed due to the above. Hence, the Kubelka-Munk theory cannot be used to predict the final brightness of the top liner, but is a useful guide in the selection of pulps when the process brightness loss is known or when past runs of a similar grade are used as a bench mark.

Data are presented to show the relative effect on brightness of simulated board of varying amounts of liners of different brightness and opacity, also the effect of blending top and inner liners with each other or with filler stock. For economical operation (minimum use of top liner), the brightness of top and inner liner is shown to be the most important consideration, assuming that good formation is obtained on the machine.

Chorine Dioxide and Safety, J. F. Haller and W. W. Northgraves

The increased use of chlorine dioxide in the pulp industry is noted. It is suggested that large-scale use of this material has been retarded in part by overemphasis upon hazards related to this compound.

Physical properties of both gaseous and liquid chlorine dioxide are described and its solubility in water is given over the range of concentrations and temperatures at which it is produced and used.

The decomposition temperature of pure chlorine dioxide is about 130°C. It is shown that this is independent of concentration at partial pressures up to 300 mm. Hg.

Experiments are described whereby the rate of propagation of chlorine dioxide explosions has been determined. This seldom exceeds 1.0 meter per sec. under the conditions that chlorine dioxide is generated. These data were used to design large-scale production units for the pulp industry.

Several qualitative experiments are described which further illustrate the nature of the decomposition of chlorine dioxide.

Studies on experimental animals show that chlorine dioxide is not dangerous in concentrations which plant personnel may tolerate without gas masks. Relatively large concentrations, in the order of 150 mm. Hg partial pressure, did not cause death in exposures up to 15 min.

Ingestion of 10 p.p.m. chlorine dioxide in drinking water over a 2-year period was not harmful.

Dye Adsorption on Wood Pulp. IV. Note on Effect of Drying of Pulp on Specific Dye Adsorption, Edward F. Thode, Andrew J. Chase, and Yee Hu

The specific dye adsorption of sulphite pulp has been shown to decrease as a smooth function of the moisture content of the pulp at termination of drying. The decrease in strength of the unbeaten pulp as drying progresses may thus be shown to be a function of specific dye adsorption. These results are interpreted to mean that the phenomenon of "irreversible cornification" greatly affects the external surface of the wood pulp fiber and thus markedly reduces the potential of the fiber for interfiber bonding.

Correlation of Dye Adsorption and Cupriethylene Viscosity Tests for Pulp Characterization, Edward F. Thode and John F. Gorham

A correlation of data on six samples of sulphite pulp from widely different sources shows that the bursting strength of pulp handsheets is principally a function of but two variables—the specific dye adsorption and the cupriethylenediamine disperse viscosity of the pulp. The indications of this work are that, irrespective of source, pulp bursting strength is largely determined by the degree of polymerization of the cellulose and the external specific surface of the fibers.

The Action of Water on Cellulose Between 100 and 225°C., B. B. Mithel, G. H. Webster, and W. H. Rapson

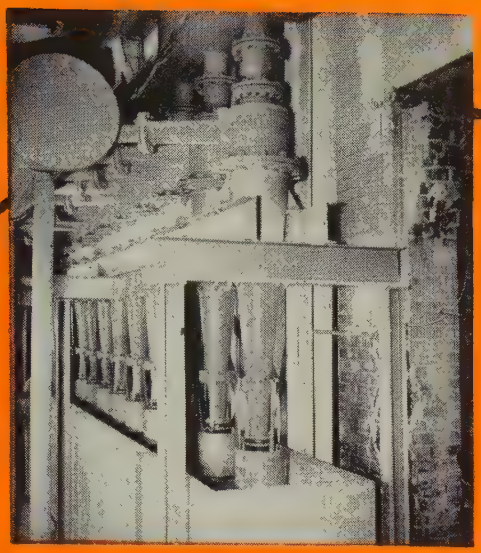
Highly purified wood cellulose (98.0% alpha-cellulose) was heated with boiled, distilled water for 4 hr. at temperatures from 100 to 225°C. Curves are presented showing the effect on viscosity; alpha, beta, and gamma-cellulose; amount of cellulose dissolved; and the pH of the liquor.

No cellulose dissolved below 170°C., but some did at higher temperatures (23% at 209°C.). Below 150°C. the alpha-cellulose content of the residue dropped only a little (95.3% at 135°C.), but at higher temperatures it fell sharply (7.2% at 209°C.). This sharp drop was accompanied by a similar sharp rise in beta-cellulose (90.7% at 209°C.), but relatively little gamma-cellulose appeared in the residue (2.1% at 209°C.). The viscosity of the cellulose dropped as the temperature was raised. These changes were accompanied by a drop in pH of the liquor (pH 6.1 at 160°C.; pH 3.7 at 209°C.).

These effects were shown to be related to the pH of the aqueous solution. When the water was buffered with phosphates, at pH 5.0 to 4.0 the effects were very similar to those without a buffer, but at pH 7.8 to 7.2 the effects were radically different. The rate of degradation was sharply lowered, about 40°C. higher temperatures being required to reach the same viscosity level in 4 hr. The amount of cellulose dissolved was higher at lower temperatures, and lower at higher temperatures. The alpha-cellulose content of the residue remained high at much higher temperatures (97.5% at 200°C.), and the beta-cellulose content remained low (1.7% at 200°C.), in sharp contrast to the effect with unbuffered water.

A possible interpretation of these phenomena is offered, based on the assumption that at any temperature the rate of hydrolysis of the cellulose is a function of the hydrogen ion concentration, and the solubility of the shorter chain cellulose molecules is a function of the hydroxyl ion concentration.

It is suggested that these reactions between cellulose and the aqueous solution are occurring in all cooking processes. They probably account for the differences which are found in the effects of acid, neutral, and alkaline cooking processes on cellulose, and the curves may be used to estimate the extent of damage to be



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The Rheology of Cooked Wood. I. Introduction, J. E. Stone

A discussion is given of the need for information relating to the mechanical work required to separate fibers after wood has been cooked or treated in various ways. An apparatus designed to break wood at elevated temperatures and pressures is described, together with some preliminary results and photomicrographs of the cell wall at the plane of failure.

The Diffusion of Sodium and Ammonium-Base Neutral Sulphite Liquors into Wood, J. E. Stone and C. Förderreuther

A comparison was made of the rates of diffusion into wood of ammonium and sodium-base neutral sulphite liquors. Two methods were used: (1) aspen blocks of different moisture contents and different lengths were heated in the two liquors at 170°C. and the extent of diffusion measured by observing the pattern of the "burnt" area inside the wood; (2) formal diffusion experiments were carried out on birch blocks saturated with water and immersed in the liquors. The distribution of chemical within the blocks after various times was determined and the diffusion coefficients calculated. The experiments were preformed at several temperatures and in the longitudinal and tangential directions of the wood.

Both types of experiment showed that there is very little difference between the rates of diffusion of sodium and ammonium-base neutral sulphite liquors into wood.

Chemical Composition of Common North American Pulpwood Barks, Ying-Pe Chang and Raymond L. Mitchell

A comparative chemical analysis was made of the barks from 24 species of North American woods. The principal components of bark determined were: ash; solubility in successive extractions with benzene, alcohol, hot water and 1% NaOH; solubility of original bark in 1% NaOH, apparent lignin, methoxyl content of lignin and bark, potential reducing sugars, and the composition of the reducing sugars by paper chromatography.

Tannins were indicated qualitatively by the gelatin test and by the formaldehyde-hydrochloric acid reaction.

The effect of 1% NaOH extraction on bark was measured with reference to apparent lignin, methoxyl in lignin, and potential reducing sugars. The amount of material precipitated upon acidifying the alkaline extract from the original barks was determined.

The heat of combustion was determined for 20 of the barks. The chemical composition of barks was compared with that for woods. General trends in the relation of chemical composition to physical structure of barks were discussed.

Bleaching Northern Kraft with Peroxides, R. E. Noreus and R. P. Hella

Jack pine kraft has been commercially bleached for approximately 1 year with a sodium peroxide stage substituted for the final caustic extraction in a four-stage sequence. Compared to a previous five-stage system without peroxide, the pulp brightness was increased from the 78 to 79 range to 81 to 83. The percentage loss in bursting strength and tear during bleaching was slightly less than previously. There was no apparent improvement in the brightness stability of the pulp or the paper made from it as a result of this peroxide stage. Paper brightness was increased equivalent to the pulp brightness increase. The additional chemical cost of $2.44 per air-dry ton was partially met by using the idle stage in a sulphite bleaching sequence with a resulting cost saving in maintenance, labor, and power.

Approximately 700 tons of the four-stage pulp have been superbleached with hydrogen peroxide applied on a wet felt machine. After a period of 4 to 12 days' storage at room temperature in laps of 30% consistency, the pulp brightness increases 3 to 5 points. The strength characteristics and the brightness stability of the pulp are unchanged by the treatment. The effect of the increased pulp brightness on paper brightness has not been definitely determined because of its use in mixed furnishes. Chemical cost of superbleaching has been $2.66 per air-dry ton.

Slime Control Chlorination in Paper Production, B. J. Twisdale

A brief description of the mill is presented and data are given on operational costs, improvement in housekeeping, effectiveness of slime control, and chemical costs.

Fresh Water System

A description of their filter plant, its location, the type of raw water treated, its source, and other pertinent data are included in this section. A description of the chlorinator installation, the operational costs involved, and the operational savings involved likewise are included. A discussion is next entered into dealing with the start-up of chlorination, then some data referring to the amounts of chlorine with residuals obtained are given. The final portion of this section deals primarily with the results achieved by chlorination.

White Water System

Again this involves a description of the white water system, the reasons why it was decided to try out chlorination, and a description of the final chlorination setup. Operational costs of chlorination are discussed; likewise, savings in costs due to chlorination are mentioned. Comparison of chlorination as a method of slime control as opposed to other methods is briefly discussed. Finally, the results obtained by chlorination are stated and discussed.

Conclusions

In this section the conclusions arrived at as a result of this paper are stated. It is concluded that chlorine meets several requirements for slime control and also pointed out that to achieve the results shown, a complete chlorination setup must be installed.

Water Pollution—Magnetic Abatement, W. R. Stemen

A three-step process for the rapid clarification of white water and a unique apparatus that is used in the third step are described. In the first step the white water is rapidly mixed with a coagulating chemical and a ferromagnetic powder. In the second step the resulting mixture is gently agitated to promote the formation of a flocculent precipitate (floc) that contains the impurities of the waste and the ferromagnetic powder. In the third step the floc is rapidly removed (5 to 25 sec.) by a unique magnetic drum.

Chemical and Biochemical Methods of Effluent Purification, Eduard Farber and Donald V. Robertson

The general problems of water supply and stream improvement have become increasingly urgent. In this serious situation, it may be helpful to reconsider, in the light of recent experiences, the four avenues to a solution of the pulping waste liquor problem: (1) evaporation, (2) precipitation, (3) insolubilization, and (4) biological conversion. Special attention is recommended to the following possibilities:

1. New experiences in desalting sea water and in avoiding scale formation.
2. Combination of different kinds of effluents containing chemical precipitants.
3. Reversal of the depolymerization of lignin in cooking.
4. Recovery of proteinaceous materials from the growing of selected microorganisms which convert dissolved lignin.

Estimating Costs for White Water Treatment, V. J. Calise and R. J. Keating

Proper selection sizing and operating of white water treatment equipment in many cases results in the saving of many thousands of dollars per year by the recovery of stock and process water in addition to solving the waste disposal problem.

The three most important factors which must be considered before waste treatment equipment can be properly selected are (1) state requirements for pollution abatement, (2) quality of water and the consistency of the stock required for reuse, and (3) the types of equipment available for treatment of the specific waste water.

Basically, the choice of equipment narrows down to (1) screen filtration without pretreatment, (2) settling in reclaimers or retention basins with or without chemical treatment for coagulation plus contact with sludge, and (3) flotation involving pretreatment with chemicals and pressure aeration followed by flocculation and skimming. The cost items which must be considered after the basic design information is available are initial cost of equipment, installation costs, chemical and labor costs. These costs must be compared to the savings in water, stock, and heat for proper evaluation of the various systems.

Use of Calender Driers and Smoothing Presses for Improving Finish, J. J. Higgins

A number of evaluations have been conducted to determine the effect of a smoothing press and primary and secondary calender driers. The installation of a smoothing press about two-thirds of the way through the drying section has improved the visual finish of coated board and also improved its surface for half-tone reproduction. On patent coated board, a smoothing press does an excellent job improving the finish of the back side of the sheet with some slight improvement to the top side.

Calender driers have had a three fold effect in improving quality. First, they permit formation of a denser sheet with an improved visual finish; second, they remove moisture added at the calender stack, therefore raising the moisture level from the drier section, thereby improving the foldability of the board; and, third, it is possible to produce a flatter sheet since the curl can be varied to some degree by the temperature in the driers.

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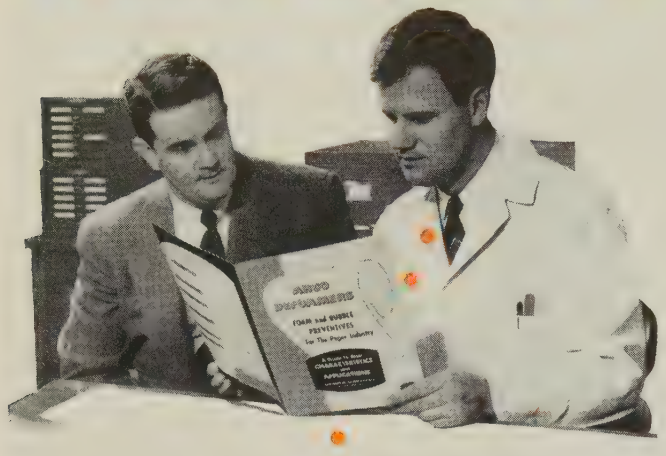

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Cohesive Rating in Semichemical Pulping, JOHN HART

The measurement of material binding fibers together in a high-yield pulp (i.e., a lignin determination) is not necessarily a measurement of the fiberizing quality of that pulp. Other factors such as the method of cooking require consideration as influences on the ease of fiberizing. This physical property of a high-yield pulp is called its "cohesiveness" and "the cohesive rating" is a numerical figure which expresses the measurement of that property in a standard procedure devised for this purpose.

The development of an apparatus and procedure are described in this paper. The apparatus consists of a laboratory Dynopulper which has been modified to give reproducible results. The procedure consists essentially of processing the pulp in this Dynopulper for a specified time and then fractionating it on an appropriate screen to determine the per cent rejects. Details of the procedure as recommended for mill operations are given in the Appendix.

This measurement may be of use as a mill control test. Thus far, the test provides results which are relative rather than absolute. Close correlation has been found in the laboratory between the cohesive rating and the refining energy under standard refining conditions, but there is a need for additional information from mill experience with this method as to correlations of cohesive rating with refining to a required pulp quality for any particular mill. A valuable, absolute test which would serve as a tool for research and control may be evolved in time from mill use of the techniques described herein.

The Liquor-to-Wood Ratio as a Variable in Neutral Sulphite Semichemical Pulping, E. L. KELLER and J. N. MCGOVERN

Several lots of aspen (*Populus tremuloides*) and white oak (*Quercus sp.*) pulpwood differing in initial moisture content were first steamed and then cooked in an experimental tumbling digester by the neutral sulphite semichemical process to compare the effects of liquor-to-wood ratios (by weight) of 5:1 and 2:1. Indirect heating was employed. Only the chemical concentration was varied, in order to keep constant the total amount of chemical applied. Pulps prepared at the lower ratio contained more pentosans and less alpha-cellulose, were obtained in somewhat greater yield, and generally were as bright as or brighter than those made at the higher ratio. Although the differences had research significance, they were probably too small to be of any practical importance.

Pulp strength, on the other hand, did not vary significantly with variation in the liquor-to-wood ratio.

Aspen pulping was not affected by the fact that, at the lower liquor-to-wood ratio, the volume of liquor present was not sufficient to fill the void space in the chips. Furthermore, it was observed that the void spaces in the chips were not completely filled even when the amount of liquor present exceeded the void volume.

All evidence pointed to uniform pulping, and presumably uniform penetration, at both high and low ratios of liquor to wood, regardless of chip moisture content before steaming and the temperature schedule used.

Although the liquor ratio is not a factor in the semichemical pulping of chips of different sizes, it was noticed that small chips were more completely pulped than larger ones under the same conditions.

Equally satisfactory results with the low ratio in a mill-scale operation will depend on satisfactory distribution of heat and cooking chemical.

Relationship of Tire Cord Properties to the Amount of Beta-Cellulose and Resistant Pentosan in the Pulp, D. D. BACHLOTT, I. K. MILLER, and W. D. WHITE

It is well known that wood pulps are inferior to cotton linters pulp in the production of high tenacity viscose rayon of the type used in the reinforcement of rubber products. Tire cords made from a conventional 95% alpha sulphite pulp are 0.1 to 0.15 g.p.d. lower in strength and have about half the fatigue resistance of cords made from linters pulp. The use of wood pulp is desirable, however, because of lower average cost and ease of processing to viscose.

In the course of cooperative programs with several pulp companies a considerable number of pulps from various woods made by the sulphate process with prehydrolysis, and by the sulphite process have been subjected to laboratory analyses and processed into yarn and cord. A comparison of the yarn and cord properties with results of laboratory analyses has shown that tire cord strength and fatigue resistance increases as the amount of beta-cellulose in the pulp decreases. With prehydrolyzed sulphate pulp from pine, cord fatigue resistance increases with decreasing amount of resistant pentosan i.e., pentosan in the alpha fraction of the pulp. With prehydrolyzed sulphate pulp from gumwood and sulphite pulp no correlation with the resistant pentosan content of the pulp was found.

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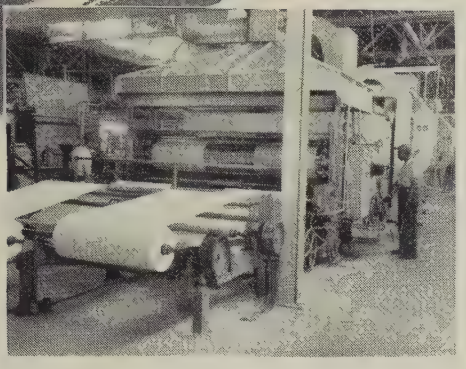

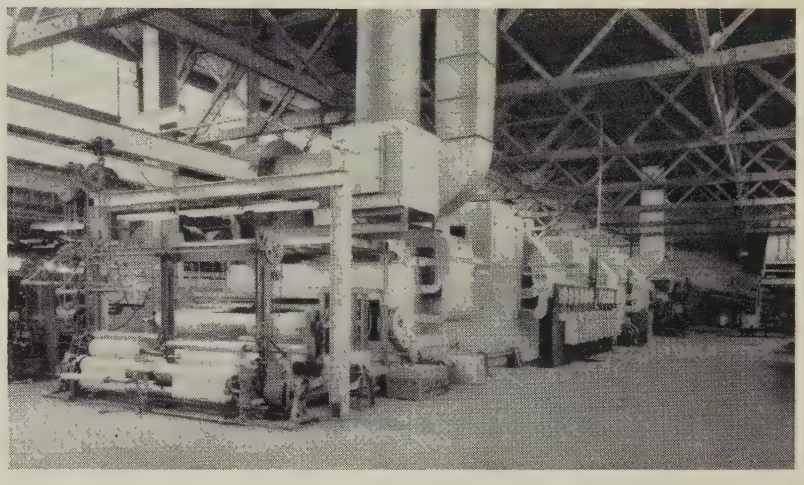

Above: Double web material being fed to WALDRON impregnator before entering the ROSS Dryer. At right: Dry end of ROSS 3-zone continuous line dryer. Second ROSS Dryer of this type is soon to be installed.

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pulps has shown that the difference between pulp solubility in 10% and in 18% NaOH solution is related to tire cord strength in the same manner as the beta-cellulose content. Solubility measurements of this type seem to be more logical and inherently capable of better reproducibility than the customary measurement of alpha, beta, and gamma-cellulose.

Correlation of Accessibility of Cellulose with Its Rate of Acetylation, Elisabeth Barabash, A. J. Rosenthal, and B. B. White

Accessibility of cellulose to a given reagent under well-defined conditions may well serve as a measure of its reactivity which, in turn, may be used to predict the acetylation behavior of the samples. Accessibility here is understood in a broad sense, as availability of hydroxyl groups to a given reagent, availability determined by steric factors, amorphous to crystalline ratio, swelling, etc.

By using a modification of Glegg's oxidation procedure, whereby the accessibility is measured as number of mols of chromic oxide consumed per glucose unit at zero time (extrapolated), it was found that wood pulp, on the whole, had a higher accessibility than cotton linters, in agreement with results obtained by other methods; the larger spread in the values with wood pulp is tentatively ascribed to purification differences. Increased moisture content of the pulp, resulting from moisture conditioning, prior to oxidation, increased the accessibility up to a certain level, dependent on the history of the sample and the nature of cellulose.

In order to correlate accessibility values obtained with reactivity, esterification rates of several celluloses of known accessibility were determined by a special optical method devised for this purpose. The results obtained showed that this accessibility will predict the clearing rate or time of acetylation but only if (1) the celluloses are from the same source and have been purified by the same procedure and (2) the moisture contents of the celluloses have been achieved by the same method.

Studies on the Use of Paper Chromatography in the Characterization of Dissolved Pulps, Jerome F. Saeman, R. L. Mitchell, M. A. Millett, W. E. Moore, and R. C. Weatherwax

In a previous paper, techniques were described for the quantitative paper chromatographic analysis of purified pulps.

This paper presents the results of an experiment in which mixtures of glucose, xylose, and mannose are subjected to treatments used in the analysis of pulps. The measured amounts of the components recovered form the basis for simplified methods of calculation, and the evaluation of errors.

A Method for Qualifying Dissolving Grade Pulps, B. G. Hoos

The usual methods of characterizing a wood pulp will not reliably forecast whether it will be suitable for high-tenacity rayon yarn. In recent years numerous other methods have been suggested, such as reactivity, accessibility, degree of mercerization and of xanthation, viscose filterability, chain length distribution, and others.

It is now generally accepted that a pulp of as uniform chain length and as high DP as possible is desirable for high-tenacity rayon yarn. But determination of chain length distribution is time consuming, quite involved, and the interpretation of the results difficult. The alpha, beta, and gamma-cellulose contents of a pulp give a very crude indication of chain length distribution.

According to the method now proposed it is postulated that, for any given dissolving pulp, the higher the alpha-cellulose content of the cellulose recovered from its alkali-cellulose which has been aged to the level of viscosity used in rayon manufacture, the more likely will the pulp yield rayon of uniform chain length distribution.

To qualify a pulp by the proposed method, portions of alkali-cellulose made from the pulp are aged for about 30 and for about 70 hr., the cellulose recovered by dilution and washing and these water-recovered celluloses are tested for alpha-cellulose content and for viscosity. The relationship of the simultaneous change in alpha-cellulose content and in viscosity of the cellulose during aging in alkali-cellulose form is linear when the ratio of alpha to non-alpha (100 minus the alpha-cellulose) is plotted against the reciprocal of the viscosity on rectilinear coordinates. The alpha/non-alpha ratio at a reciprocal of 0.15, i.e., 6.67 cp. viscosity, is arbitrarily designated as the H-test value. Thus, a single value is obtained by a simple method which gives an indication of the uniformity of the chain length distribution of the pulp.

Data are presented which show the effect on the H-test value of the degree of cooking, purification, and bleaching of wood pulp.

Reducing the Dirt Content of Unbleached Sulphite Pulp with Centri-Cleaners, A. B. Gorham

The Ontario Paper Co.'s sulphite mill at Thorold produces 200 tons of unbleached sulphite pulp daily. Approximately 130 tons of this production are required for newsprint furnish while the surplus amounting to 60 to 70 tons per day is improved in cleanliness and sold in dry bales as export sulphite.

After the war the demand for clean sulphite prompted us to seek ways and means of reducing the dirt count of our product and the newly developed Centri-Cleaners were investigated. The larger type (no. 620) was tried out first, but results were not good enough to warrant an installation. The smaller type (no. 600) cleaner was then investigated when a single cone was obtained for experimental purposes. The results of these tests were very encouraging as they indicated that a dirt reduction in our sales pulp of 65 to 68% would be possible.

The initial installation in out mill did not give us the dirt reduction indicated from the results of our trial with one cone. This poor performance was traced to the high consistency of the stock fed to the cleaner. By installing additional units in order to handle the stock at a reduced consistency the efficiency of the cleaners was raised to the 65 to 68% range obtained with the experimental unit.

The above-mentioned installation consists of eight clusters of primary cleaners. The rejects from these units amount to 12 to 15 tons per day. Two clusters of secondary units were later installed to reclaim approximately 10 air-dry tons of clean pulp from these primary rejects. This has effected a considerable saving by replacing lower yield sales pulp with higher yield news pulp in our paper machine furnish.

Operating difficulties experienced with the start-up of the smaller cleaners are mentioned and the steps taken to correct them are described. As a result of installing the equipment referred to in this paper it has been possible to do away with flat screens.

The Development of a New Stock Refining Process and Its Application to Cotton Linters, E. H. Cumpston, Jr.

A brief history of the development of a new pulp refining method is presented, beginning with the desire for such a method and tracing the development process through to the final embodiment in a refining machine. The first concrete step was the construction of a turbulence machine which proved worthless for refining but invaluable for guiding succeeding steps. The trail next led through fiber on fiber, small clearance, impact, and so-called microrefining techniques. This work led to the selection of high pulp consistencies as a prerequisite. Means for the uniform and controllable circulation of consistencies over 20% were considered and one technique was selected and carried to a machine design. The type of fiber treatment achieved and the operating characteristics of the machine are discussed and some conclusions drawn. The application of this machine to cotton linter pulp is covered briefly and some data are presented. Slides will be shown.

A New Sizing Agent for Paper—Alkylketene Dimers, J. W. Davis, W. H. Roberson, and C. A. Weisgerber

Alkylketene dimers* are now being used commercially for sizing paper. In contrast with the conventional rosin-alum complex which exists as agglomerates on the surface of the paper fibers, these compounds actually react with exposed hydroxyl groups on the fibers to form chemical bonds. This reaction with the fiber surface gives rise to a very hard and permanent type of sizing. Ketene dimers require no alum and can be applied under either acid or alkaline conditions. They can therefore be used on stocks containing alkaline fillers or on sheets in which it is desirable to omit alum or other electrolytes. Paper sized with alkylketene dimers exhibits a relatively high degree of resistance to lactic acid solutions, to alkali solutions, and to other strong penetrants.

Alkylketene dimers are liquids or low-melting solids. Mixed with suitable emulsifiers, they are readily dispersible in warm water. Their emulsions or dispersions are compatible with starch, CMC, and most of the usual paper-treating materials and can be applied to the paper web at the calender, size press or tub, or by means of a coater. Spray application offers a convenient way to apply controlled amounts of alkylketene dimer emulsions to an unsized sheet. The operability of this method of application has been successfully demonstrated on commercial paper machines. Sizing is usually developed by the time the sheet is dry, but drying conditions must be sufficient to bring about the necessary chemical reaction. Normal paper machine operating conditions have usually been satisfactory.

Because they are effective at very low concentrations, alkylketene dimers are expected to complete economically with rosin size in many grades of paper. Their effectiveness without alum and their resistance to strongly acid or alkaline penetrants make them useful in the development of new grades of sized papers.

Deculator-Cleaner Process, J. C. Stewart

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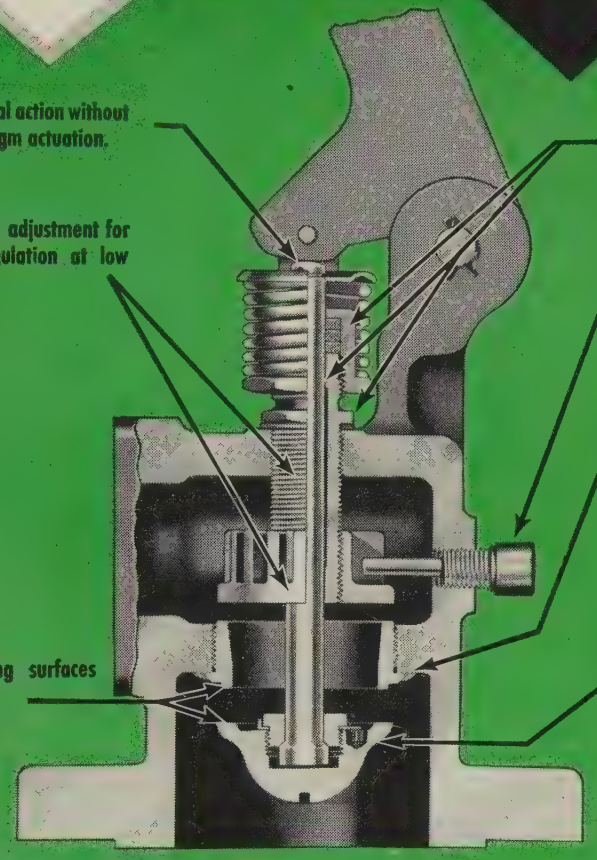
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paper industry personnel, the Deculator-cleaner process has been developed for the simultaneous removal of air and dirt from paper machine headbox furnish. A Deculator-cleaner system was recently put into operation on a large bleached kraft food board machine in the south. Additional installations are being made on other machines producing grades such as kraft board and paper, bleached kraft, tissue, and specialty papers.

This new development combines the Deculator process and a battery of Bauer cleaners. Standard Bauer cleaners incorporating minor modifications are mounted on top of the Deculator vacuum receiver in an inverted position. The accepted stock discharging from the cleaners is sprayed into the receiver against impingement areas. The high vacuum existing within the receiver for stock deaeration is applied to these accepted stock discharges, thus producing a portion of the pressure drop required for operation of the cleaners. The inlet pressure to the cleaners is reduced by the amount of the vacuum giving substantial savings in pumping horsepower. The "packaged" combination is complete with all interconnecting piping for the cleaners and the Deculator receiver, resulting in considerable reduction in the cost of installation and piping, together with reduced space requirement for the combined equipment.

Extensive tests and operating information have proved that the combination of cleaners and the Deculator process offers dirt, as well as air and gas, removal equal to the equipment installed separately. Our development determined that the accepted stock discharge from the cleaners produced a spray pattern when introduced into the vacuum receiver comparable to that offered by the usual Deculator stock spray nozzles, making the combination feasible.

Many other advantages are gained through the Deculator-cleaner process combination. On one typical installation stock will be cleaned and deaerated at a consistency higher than required for the headbox. Additional white water for dilution will be drawn into the Deculator receiver through spray nozzles and deaerated by the vacuum in the receiver. The cleaned and deaerated stock and the deaerated white water mix in the receiver and the mixture is pumped to the headbox at the required consistency.

Reports on operation of the bleached kraft food board machine installation have been extremely favorable, indicating high cleaning efficiency and definite improvements in formation of the board being produced. This new development has aroused much interest by offering economies in cleaning and deaeration of papermaking furnishes.

Surface Properties of Rosin Size Precipitate. III. Electrokinetic Properties of Rosin-Sized Wood Pulp Fibers, Edward F. Thode and Shwe Htoo

Stream current experiments have been conducted on pads of wood pulp fibers sized with rosin-aluminum sulphate complex in order to determine the electrokinetic potential, or surface charge of sized fibers.

The results show that pulp in dispersion with 3.0% aluminum sulphate present is negatively charged (zeta potential, −4.1 mv.), but when 2.4% rosin size is also present the charge on the sized pulp is positive (zeta potential, +7.9 mv.). It is concluded that the hydrated aluminum ion is adsorbed primarily on the rosin size in the process of sizing pulp with rosin size and aluminum sulphate.

Foreign materials added to the sized pulp system produce changes in the electrokinetic potential of the sized pulp similar to those observed for rosin size precipitate alone.

With only rosin size and aluminum sulphate present in the system, along with the pulp, pH is related to electrokinetic potential as expected, because both depend on the same reactions. Addition of other materials destroys this relationship.

Surface Properties of Rosin Size Precipitate. IV. Influence of the Electrokinetic Potential of Rosin-Size Precipitate on Sizing Efficiency, Edward F. Thode, John F. Gorham, Ralph W. Kumler, and Norman T. Woodberry

Information on the electrokinetic properties of rosin-size precipitate presented in previous papers is correlated with results of sizing tests conducted on laboratory-prepared handsheets. It is shown that changes in sizing efficiency parallel closely changes in the electrokinetic potential of rosin-aluminum sulphate complex as the proportion of aluminum sulphate to rosin size in the system is altered. Similarly, changes in sizing efficiency induced by the presence of small amounts of contaminant materials usually correlate with the changes in electrokinetic potential of the size precipitate, unless the contaminant has sizing properties of itself. It is concluded that the electrokinetic potential (or, effective surface charge) of the rosin size precipitate is one of the major factors influencing sizing efficiency. In the usual sizing pH range (4.2 to 5.5) variation in the electrokinetic potential has more effect on sizing efficiency (as measured by the ink penetration test) than does change in the pH. On the basis of these findings, a modification of the electrokinetic theory of sizing is presented and its application in explanation of practical sizing problems is discussed.

Variable Voltage Drive—The Principal Advantages and Disadvantages, Fred A. Leser, Jr.

This paper will concern itself primarily with a basic definition of the direct current drive, the reasons for its use, and specific applications of the drive to the major production machines found in the average corrugated container plant.

The Use of Various Starches in Corrugating, Kurt A. Wohl and Paul Kaplan

The basic properties of various starches such as corn, wheat, and tapioca are discussed. In addition, information gathered from actual plant operations covering the use of these starches in the corrugating process is presented. Data concerning the mixing, storage, machine performance, etc., of these starches are included.

Research Project into Machine Design for New Corrugator, W. Ward

The crown of the corrugating rolls and pressure roll in a single facer determines the "nip" pressure just as in a calender stack on a paper mill. Once the rolls have been crowned there is only one nip pressure which can properly be attained. Heavier journal loading will cause the rolls to bear harder near the edge of the sheet and more lightly in the center. Lighter journal loading reverses this with the edges of the web having a lower nip pressure than the center.

Proper loading throughout their life of a well-made pair of corrugating rolls will produce even wear within the average paper width run. We have inspected numerous pairs of rolls returned for recutting and have found this to be correct.

A vital part of our inspection of new rolls is to check diameter every 2 in. across the face of the roll. From these readings a curve is plotted and kept as a permanent record of the roll. Such rolls are again inspected when returned for recutting and a similar curve again plotted. Comparison of these two curves has indicated that the same crown curve still exists within the average width of paper run. Seventy-eight-inch rolls run on an average width of 65 in. will wear off as much as 0.025 to 0.030 in. in diameter yet the center 65 in. of face width still has a curve equal to the original curve within a matter of 0.002 to 0.003 in. in diameter.

The lower roll of such a pair, which in our case is cut with no crown, will maintain a cylindrical shape over the 65 in. of face width. This even though it may have worn more than 0.030 in. due to the additional wear of the pressure roll.

The Influence of the Filter Medium on the Filtration of Viscose, W. E. Davis

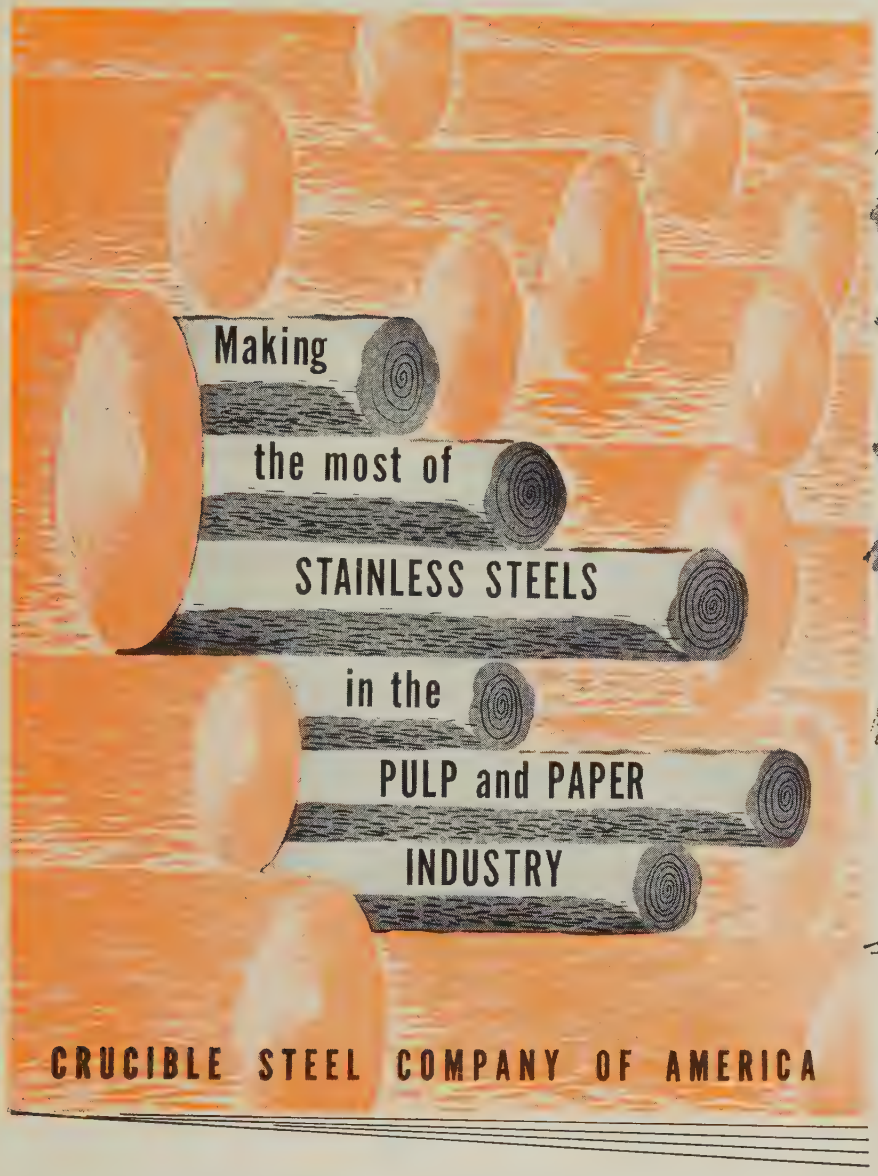
Hermans and Bredee have shown that to a good approximation the removal of suspended material from viscose occurs as if the filter were an assemblage of fine capillaries whose diameters are gradually reduced by deposition of material on their walls until plugging occurs. Their assumption concerning the rate of deposition leads to a linear relation between t/v and t, where t is time and v is volume filtered. However, this assumption also leads to a relation between filter thickness and fraction of filter-plugging material removed which is physically impossible. If we make a different assumption regarding rate of deposition, one which yields a reasonable relation between thickness and fraction removed, we find that it also leads to a type of curvature in the plot of t/v against t which is actually observed with thick filters.

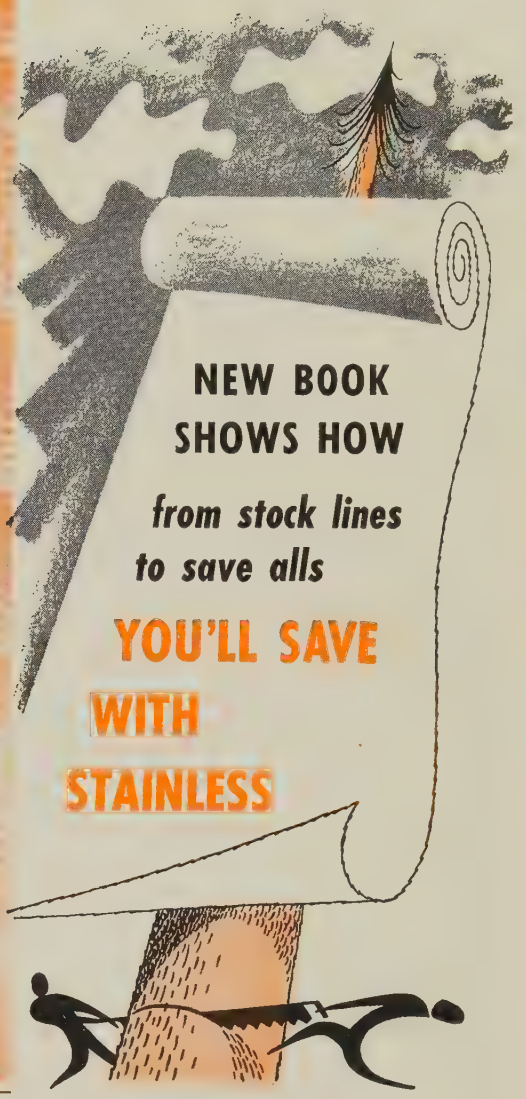
The new assumption thus has a certain amount of experimental support, and it is of some interest to explore its consequences for the practically important aspects of the filtration of viscose and other solutions containing suspended gel particles. This paper develops the effect of the new assumption on such matters as constant-rate filtration, prediction of filtration efficiency, design of filter media, and the setting up of a filtration cycle to make the best use of a given filter material.

Laboratory Evaluation of Viscose Filterability with Different Filter Media, E. E. Hembree

Filtration properties of viscose are of predominant importance to producers of viscose. Many factors in the history of the cellulose and in the preparation of viscose influence these properties. Filtration is affected by the process used for purification of the cellulose and the degree of purity and polymolecularity. The origin of the unpurified cellulose, whether cotton linters, hardwoods, or softwoods is an influencing factor. Filterability of viscose varies with conditions under which it is prepared, and with cellulose and caustic contents.

Undissolved particles in viscose vary in size from a few microns in diameter up to several hundred microns and may be classified into four major groups: (1) nonfibrous gelatinous bodies, (2)





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highly swollen partially disintegrated fiber fragments, (3) intact fibers, swollen but retaining some characteristic markings, (4) silica and metallic salts.

A factorial arrangement for filtering viscose prepared from two types of pulps through three filter media was set up to permit evaluation of the precision obtainable with each medium and to indicate the filterability rating of the two pulps by the three media.

Standard deviation of filter A, composed of flannel, filter cotton, and sheeting, was ±7.5%; filter B, composed of flannel, filter paper X, and sheeting, was ±9.6%; filter C, composed of flannel, filter paper Y, and sheeting, was ±12.4%. The three media gave different filtration values and rated the two pulps differently. Filter medium A showed viscose from pulp II to filter four times as much as viscose from pulp I before plugging, filter medium B showed the filterability of pulp II to be 21 times as much as pulp I, and filter medium C showed filterability of pulp II to be 17 times as much as pulp I.

Undissolved particles visible at 200 magnification and counted in 750 fields per drop of viscose totaled 109 for unfiltered viscose from pulp I and 3 for pulp II. One filtration through the filter cotton medium removed 51% of the particles from pulp I viscose. With the industrial-type filter paper 94% of the undissolved material was removed.

Characterization of Pulps via Integrated Filtration and Optical Studies on Their Viscoses, Michael Golben

The filterability test, in its many forms, has been a useful tool in evaluating dissolving pulps by means of their viscoses. However, by itself, it does not describe viscose quality adequately. Unfiltered viscoses made from commercial pulps contain small, undissolved particles varying widely in nature, shapes, and size distribution for different types of pulp. The character and predominant size distributions of these particles have an important bearing upon viscose filterability, viscose clarity, yarn appearance, and yarn physical properties. It is therefore important to obtain more complete information about the nature of unreacted residue in viscose.

In an integrated series of tests, a pulp to be evaluated is converted into viscose under standard processing conditions. Samples of this viscose are examined under the microscope to obtain preliminary information about the undissolved particles, ranging in size from large, swollen fibers of 60 to 100 mu or more in diameter down to submicroscopic sizes. A standard quantity of this viscose is passed through a five-layer filterability unit of a constant rate filterability tester. The slope of the pressure-time curve so obtained is the T-value, a measure of filterability. It is recognized that only the larger group of particles will cause clogging and affect the T-value. The five layers of the filter media are stripped and washed individually. Particle counts are made on aliquot portions, with particles defined as fibers, fiber gels, gels, skins, crystals, and dirt. A measure of the turbidities of the suspensions obtained from the five layers is made, as well as their light-scattering properties by nephelometer. The data for the five layers can be graphed to show a "turbidity profile," which reveals the position of maximum concentration of particles in the filter media. This information can be related to effect of a given viscose upon production filters and quality of filtered viscose. The ratio of the transmittance of the composite sample to its nephelometer turbidity is called the "clarity number," representing the sum total effect of large particles which affect filterability and small particles which affect viscose clarity and/or yarn physical properties.

Laboratory Preparation of Alkali Cellulose According to the Slurry Steeping–Continuous Shredding Process, Milton O. Schur and Peter C. Muffat

Laboratory apparatus is described and a procedure given for the preparation of alkali cellulose under reproducible conditions according to the method of slurry steeping and continuous, one-pass shredding. Typical data are presented.

Some Viscoelastic Properties of Laminated Glassines, R. T. Nazzaro, W. J. Brand, and S. R. Arnold

Stress-strain curves for several sets of laminated glassines were obtained and compared for their plastic properties. The instrument employed was a Tinius Olsen stiffness tester of 1 in.-lb. moment capacity with a range from 0.005 in.-lb. to in.-lb. The actual moment capacity used to obtain test results was 0.015 in.-lb. The curves were obtained from continuous stiffness tests and are similar to curves produced in tension testing.

While the purpose of the instrument is to portray the stiffness of a sheet of paper, in this instance laminated glassine, it is possible to plot a load scale reading against angular deflection in degrees up to 90° and, by so doing, project a characteristic flow of the paper under an applied stress.

Samples of glassine were selected with differences in furnish composition and with plastic concentrations ranging from none to 12% by weight of the fiber. The effect of the plasticizer on the ability of the sheet to assume an applied stress with more facility is very clearly indicated by the series of diagrams accompanying this paper. This type of measurement is compared to the more static instrumentation methods such as bursting strength, tear, stiffness, and tensile testing and illustrates differences in behavior that are not found by using conventional methods of measuring.

In the authors' opinions the stress-strain diagram obtained from stiffness testing on the Tinius Olsen tester can be related to performance of glassine on packaging machinery and with more significance and reliability than the usual tests currently used on laminated glassine for this same purpose.

A true proportional elastic limit does not seem to be easily determinable from the diagrams so that modulus of elasticity in stiffness was not calculated. However, it is believed that elastic limits do exist for laminated glassines if a greater sensitivity of the instrument is selected. The general outline of the stress-strain diagram is one of plastic flow and recovery with a decided permanent set for all laminated glassines but with decided differences also noted dependent upon the construction of the laminated sheet. More plastic flow and set seems to be the general expression of a plasticized sheet compared with one without plasticizer or less plasticizer.

Warehousing, Shipping, and Material Handling of Carton Packed Paper, S. W. Blanchard

A description of the new 216,000 sq. ft. warehouse for palletized paper at The Mead Corp. in Chillicothe, Ohio, is given. The location of items by rate of turnover rather than by grades was used to cut down the ton-mile haulage. Material-handling equipment of fork lift walkie trucks for very short hauls, stand-up rider fork trucks for pickups, and an automatic pallet hoist for lowering loaded pallets from the second to ground floors are described.

A brief description of order writing, manifest, and billing by use of business machine punched cards is given.

The Acumeter System for Handling Wet End Additives, John E. Ward

The number and variety of wet end additives are running ahead of the development of equipment to apply them continuously. Frequently mills are forced to use time-consuming makeshifts to meter various additives into the stock. The Acumeter is described as a versatile unit for metering and emulsifying a wide range of additives from thin liquids to heavy pastes. Solids which melt below the boiling point of water can also be handled. The design and construction of the Acumeter equipment is illustrated, and several typical applications are described. Savings in space, handling, and equipment cost can be effected.

Weber Remote Control Edge Alignment, Paul W. Jacobsen

Remote control edge alignment avoids hunting and overcontrol by automatically duplicating manual adjustments required for webs having long spans between unwind roll stand and converting operation as well as duplicating manual adjustments required for slow moving webs.

There is no forcing or deflecting of the web for alignment at the converting operation. The web is permitted to peel off the unwind roll in a relaxed condition except for desired paper tension. This is possible because all correction adjustments are made by shifting the unwind stand just as the operator does manually.

The amount of shifting of the roll stand, the waiting period for the last roll stand correction to run in before making another adjustment, the re-evaluating of the new position of the web are all automatically timed and carried out just as a thinking operator would perform the operations; the difference being that the remote control edge alignment is in constant attendance and does a more accurate job of aligning than can be performed by the operator, though the unit follows the same correction procedure.

Infrared Heating in the Paper Industry, W. L. Thomson

Infrared heating dates back some 20 years to the original use of lamps for drying automobile finishes.

Because infrared is fast as compared with gravity convection, and because the electric heating medium has many advantages in terms of ease of application, control, and availability, the medium has become widely used as an industrial tool for heating without contact.

The increasingly exacting demands of industry have led to the development of the metal sheath for infrared radiant source operating at a maximum temperature of approximately 810°C. The long, invisible wavelength produced by these temperatures has value in terms of high intensity, relative insensitivity to pigmentation and metal sheath source and brings benefits in terms of durability and freedom from damage by shock or splashing.

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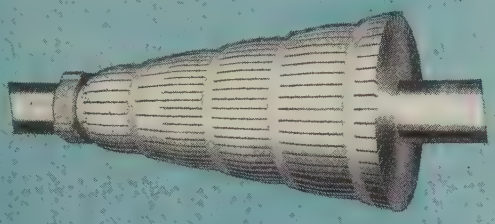

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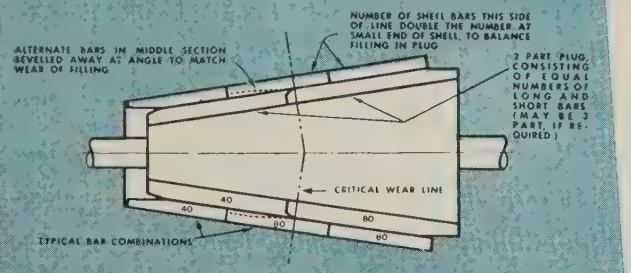
Greylock Shell Filling. Pre-assembled in a rugged conical assembly. Harrigan design with patented Nowave feature. Bars and woods of any desired standard materials.


NUMBER OF SHELL BARS THIS SIDE OF LINE DOUBLE THE NUMBER AT SMALL END OF SHELL, TO BALANCE FILLING IN PLUG
ALTERNATE BARS IN MIDDLE SECTION BEVELLED AWAY AT ANGLE TO MATCH WEAR OF FILLING
2 PART PLUG, CONSISTING OF EQUAL NUMBERS OF LONG AND SHORT BARS (MAY BE 3 PART, IF REQUIRED)
CRITICAL WEAR LINE
40
40
80
80
80
TYPICAL BAR COMBINATIONS

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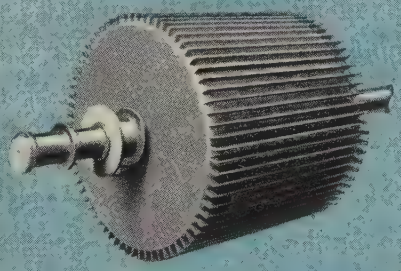

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extrusion laminating of polyethylene, and drying paint on wallpaper.

In papermaking, installations as large as 1000 kw. are in use for setting coating on-machine and preventing picking on the drier, and in preheating wet sheet in order to increase drying capacity of existing machines.

Possible future uses include selective drying across the sheet and beefing up the drying capacity of existing machines as well as curing synthetic resin additives such as melamine and urea formaldehyde for high wet strength.

An Evaluation of Drying Concepts, Part II, Anthony J. Cirrito

The fundamental principles in paper drying are reviewed with respect to factors outside the cylindrical drier which affect heat and mass transfer or evaporation. Emphasis is placed on the equilibrium between heat and mass transfer as pivoting about the evaporation temperature. The limitations of the equilibrium equation are considered as well as the practical signifiance of each term. The evaporation temperature is directly related to the vapor pressure. Evaporation increases with this pressure when the ambient air conditions remain fixed. The effect of air velocity on evaporation is also a major factor. For order of magnitude calculations, curves are appended which show mass transfer coefficients versus air velocity and evaporation temperature. These are for evaporation occurring over a 2 ft. long wetted area.

The fundamentals are related to machine conditions and performance. To facilitate field investigations, a method is given for approximating the amount of steam condensed in each drier. This is done from a knowledge of the total evaporation or steam condensed on the machine and a record of the pressure and drier surface temperature for each drier. The limitations of this technique are also given. For analytical purposes, the drier surface temperature is regarded as the factor which separates external variables from variables inside the drier shell which affect heat transfer and evaporation.

Finally, the importance of felt contact pressure is reviewed with respect to concepts by others on the nature of the resistance between the sheet and the drier. This includes the part that air plays and the effect of sheet-to-felt liquid phase transfer on evaporation.

Maintenance Cleaning with Chemicals, L. B. Wilson

The problem of unwanted deposits in piping and equipment is found in every paper mill. Such deposits interfere with operations by retarding heat transfer, impeding fluid flow, or contaminating the product.

Chemical cleaning methods have come to be accepted as an effective maintenance tool for the removal of such deposits. During recent years, however, new developments in solvents, equipment, and techniques have greatly broadened its application. Improvements in acid inhibitors have provided increased protection for metal equipment during cleaning. Case histories of boilers that have been chemically cleaned 20 to 30 times without being damaged, testify to the safety of the cleaning operation.

Performance data, before and after chemical cleaning, show that increased efficiency of operation frequently pays back the cost of the chemical maintenance in a short while. Periodic cleaning of black liquor evaporators has proved a worth-while procedure, insofar as maintaining peak capacity of the equipment is concerned. In many cases, such cleaning operations can be conducted on individual evaporators, without shutting down plant operations.

Boilers and heat exchangers are another application for chemical cleaning that result in substantial savings in operating costs. Many newer design boilers, with more complicated tube arrangements, short radius bends, and complex drum internals, preclude the use of mechanical cleaning methods.

Another important application for chemical cleaning is in the removal of scale accumulations from pipe lines. Fresh water lines, product lines, and sewer lines all tend to build up deposits, restricting flow and reducing operating capacity. The development of mechanical cleaning aids, such as "pigs" or self-propelled "moles," embodying wire brushes and high-velocity jet streams of solvent, has greatly speeded up such cleaning operations, as well as resulting in increased economy by reducing the amount of solvent required.

Many other types of paper mill equipment have been successfully cleaned, using chemical solvents. Drying rolls, pressure filters, water jackets, precipitators, water wells, in fact, any equipment which is in contact with fluids and can build up a coating of deposited impurities, have been quickly and economically cleaned by this method.

Taking into consideration such factors as reduced production, replacement costs, increased heating or cooling costs, minimum of supervision, and releasing of skilled craftsmen for other work, chemical cleaning is a valuable maintenance tool which should be utilized by every paper mill.

Analysis of Paper Fillers by Spectrographic Methods, Louis C. Block and John Lewis

Eight samples of paper with "known" filler content were obtained for analysis by spectrographic methods. The analysis for the paper was limited to a qualitative determination of the elements present in the filler materials.

The samples were initially ashed in a muffle furnace and were then mixed with graphite preparatory to excitation burning. The characteristic radiation was attained by inserting the mixture inside a cavity of a carbon electrode and striking a 5-amp. d. c. arc. A Baird three-meter grating spectrograph was the instrument used for securing the characteristic spectra.

The spectra for all eight samples were taken on an Eastman-type II-0 spectrographic plate. After darkroom processing, the plate was analyzed using suitable optical measuring instruments and the proper identifying charts and tables.

The results obtained from the spectrographic qualitative analysis for the fillers present in each paper sample were then compared with the initial listing of the fillers known to be present.

The comparison of the results showed a very high correlation between the analyzed values and the listed filler materials. These favorable results bring to light the hopeful possibility of using the spectrograph as an analytical tool which should be used by the paper industry.

The advantages attained from spectrographic analysis may be summarized as follows:

1. The amount of sample needed for analysis is very small.
2. The nature and complexity of the sample are immaterial to the analytical procedures. The identity and the concentration of all the unknown elements in a sample are determined in a single operation.
3. A permanent record is obtained.
4. Spectrographic determinations are so sensitive that the presence of elements may be reported which would normally be undetected by conventional chemical methods.
5. The time to complete an analysis is only a fraction of the time required for analysis by wet chemical method. The complete qualitative analysis for all eight paper samples was concluded in less than 3 hr.

The Determination of Starch in Paper, J. L. Harvey and B. W. Forshee

Three methods for determining starch in paper have been evaluated, namely the present TAPPI Standard (T 419 m-45), the maltase enzymatic method of Brobst and Langlois, *Tappi*, 34–38 (May, 1951), and the colorimetric method of Browning, Bublitz, and Baker, *Tappi* 35: 418 (Sept., 1952).

It was found that considerable quantities of materials capable of reducing Fehling's solution are removed from many pulps by water-extraction alone. For the 15 chemical wood pulps and rag halfstocks examined, water-extractable reducing material ranging from 0.04% equivalent starch for a bleached linen halfstock to 1.12% equivalent starch for a bleached hardwood soda pulp was found. Using an enzyme, even larger quantities are extracted. The extractable reducing material in the bleached coniferous sulphite pulps examined ranged from 0.29 to 1.08%, as starch. As there appears to be no means of correcting for or eliminating this interference, methods based on the reducing value of the extract would seem to be less desirable than a colorimetric analysis based on formation of the starch-iodine complex, since the latter reaction is highly specific. Extractables from materials normally expected in paper would not be expected to interfere with a colorimetric determination based on this reaction.

A study of the colorimetric method is reported. The method of Browning, Bublitz, and Baker is generally satisfactory, but several slight changes are suggested. The chief limitation in accuracy is the differences in color produced by various types of starches. Consideration must be given to these color differences. It is also necessary to control time, temperature, and acid concentration during the extraction. Maximum absorption for all starches occurs in the neighborhood of 580 mmu. At this wave length, Beer's Law applies for starch concentrations between 0 and 100 micrograms per ml. It is recommended that the colorimetric method be adopted as the TAPPI Standard.

Patent Office Practice, Frank Makara

It is the purpose of the Patent Office to grant patents on patentable inventions. Only those inventions which are beyond the general skill of the art are patentable. If an improved result is but the expected result or the obvious result to those skilled in the art, it is not an improvement such as would be worthy of patent protection. In other words, the contribution to the art is not a contribution at all because anyone skilled in the art would readily come up with the same answer, if presented with the problem.

Although what is patentable is in reality a legal problem, of necessity the personnel of the Patent Office must pass upon the invention although such personnel are not part of the judiciary.

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Examining an invention to see if it is patentable is the primary work of the Patent Office. For this purpose, the Patent Office has about 70 divisions each of which has about 10 examiners. The Patent Office also registers trade-marks if such are deemed to be registerable by the personnel of the office. The Patent Office also issues design patents for inventions of an ornamental nature, that is, appealing to the sense of sight.

The Patent Office provides a public search room containing all granted patents in classified order. Furthermore, the file wrappers of issued patents presenting all the correspondence regarding the invention are available upon request by anyone.

The preparation of a patent application involves a full, clear, and concise disclosure both by way of a drawing and by way of descriptive words of at least one embodiment in the case of a mechanical invention and by way of several embodiments for chemical cases. The specification must end with a claim or set of claims each of which defines an inventive embodiment of the over-all invention.

The measure of patent protection resides only in the allowed claims.

Where two inventors file applications for the same invention and both are pending before the Patent Office and interference is declared to determine who is first inventor. It is possible for one who files later to be declared the true inventor.

Where a final rejection of an application is made, appeal therefrom may be made to a Board of Appeals in the Patent Office. If an unfavorable ruling is handed down by the Board of Appeals, the aggrieved party may appeal to the courts.

The registration of trade-marks used in interstate commerce is also a function of the Patent Office. One's right to a trade-mark rests on first usage of the mark.

Design patents are granted to protect ornamental features, that is, those features visible to the eye. The period of the protection varies from $3^1/_2$ to 14 years depending upon the fee paid.

Recent Court Decisions in Patent and Trade-Mark Cases, FRANK MARKARA

Generally speaking the Federal District courts are carrying out the rule of the Supreme Court of the United States in the famous gadget case, also known as the A & P case.

In this case the patented pull carriage, used in A & P supermarkets to pull a customer's groceries deposited on a table in front of the pull carriage, was before the court. The court held such improvement as trivial and not to be worthy of patent protection since it was a gadget within the ordinary skill of the art.

The result is that in 1954, in about 70% of the patent cases appearing before the Federal District courts the patents were held invalid for want of a patentable invention.

However, the courts still assert that the claims in a granted patent are presumed to be valid and that anyone contesting this fact must prove that the claims are invalid. Darysn Labs. Inc., vs. Lenox Labs., D. C. New Jersey 101 USPQ 50.

In rejecting an invention on prior art the Court of Customs and Patent Appeals, In re: Flick and Bower 101 USPQ 70, stated that a combination reference need not show the part relied upon in a manner capable of being bodily substituted.

Unfair competition cases if they are combined with a patent question triable in a Federal Court will be handled in the court though if it were without the patent question it would be triable in a state court.

An assemblage of old parts or elements is patentable only when the whole structure in some way produces a result which exceeds the sum of its parts.

In an important case involving Helene Curtis Industries, *et al.*, District Court Southern District New York 101 USPQ 220, it was stated that where a patentee asserts a broad invention regarding use of mercaptans in hair waving lotions he cannot later in Court claim his invention relates to use of critical amounts when the criticality of the amounts was never disclosed to be the invention.

Generic claims are generally held to be invalid if they embrace inoperable specie.

Critical results if they produce a difference in kind may be patentable over the prior art showing a broad disclosure.

When a patent is before a Federal Court on the question of infringement, the meaning of the claims is obtained from a reading of the specification, the file wrapper, and the prior art.

In Hartley Pen Company, vs. Lindy, the District Court Southern District of California held that a shop-right, obtained by a company on an employee's invention, is an irrevocable, nonexclusive, nontransferable license to use the invention.

The decisions in the trade-mark field are of interest because trade-mark law is not as definitely established as is patent law.

In the Giddings and Lewis Machine case 101 USPQ 112 it was held that a use of a mark in correspondence, leaflets. etc., is *not* a trade-mark use. A trade-mark use means use on the goods being traded.

Two or more marks may be used together, for example, Hudson Admiral insect duster.

An originator of a trade-mark has nothing to transfer where he has no business, and hence no good will in the mark, there being no product, or inventory to transfer. (101 USPQ 206.)

Mere adoption of a trade-mark creates no rights, but adoption plus use does create rights. Ordering labels and listing in catalogs is *not* a trade-mark use.

A diamond-shaped pattern on steel plate is not registerable as a trade-mark where the shapes perform a useful function such as nonskidding, 101 USPQ209. Similarly a red line on a wrench is not capable of trade-mark registration where the line fills in a cavity.

"Consistently Superior" is not capable of registration under Section 2 (f) of the Trade-Mark Act permitting registration of marks otherwise unregisterable that have become distinctive by 5 years' use. It is a statement available to all.

A trade-mark adjudicated in Federal Court as being good in a number of states may be registered for said limited territory. 101USPQ 340, Commissioner of Patents.

Where services are performed in one state yet under a Federal Interstate Act, such services are capable of being registered as Service Marks on the Federal Register.

Brightness Reversion of Bleached Kraft Pulps, S. M. ROLLINSON

A study was made of the brightness reversion, or yellowing, which occurs when bleached kraft pulps are heated. The pulps used were all kraft pulps prepared from slash pine by a bleaching sequence of chlorination, caustic extraction, calcium hypochlorite oxidation, caustic extraction, and calcium hypochlorite oxidation.

Extensive washing, thorough caustic extraction, and the maintenance of high pH during the hypochlorite stages were all found to reduce reversion.

The yellowing tendency of a fines fraction (average fiber length 0.7 mm.) was shown to be only 70% that of the unfractionated pulp (average fiber length 2.4 mm.).

The presence of added iron was found to increase the extent of brightness reversion, but attempts to increase color stability by the removal of the iron normally present in pulp with Versene (an organic chelating agent) or by hydrochloric acid extraction were unsuccessful.

The colored water-soluble materials which are formed during the accelerated aging of pulp were studied both by light absorbance methods and chemical analyses. The possible relationship between these colored bodies and the colored material formed during the heat degradation of low molecular weight carbohydrates was studied by experiments with isolated hemicelluloses.

The Counteraction of Kraft Mill Odors, JOHN M. VON BERGEN

The sources of kraft mill odors, the odor characteristics, and intensities are reviewed, and a comparison of the various analytical procedures for measuring odorous compounds in the gas effluent is made with the practical technique of organoleptic appraisal. A critical review of odor control methods is made. These methods include stack dispersal, combustion methods, adsorption techniques, odor modification, scrubbing, and political. The principles of odor counteraction are defined, and the technique for determining odor pairs is explained. A relatively simple and effective method for the application of odor counteractants to odor nuisance sources at the mill is discussed, and the advantages of this method of application are described. A method for making area and aerial surveys is proposed, and the difficulties of objective appraisals are explained.

Odor counteraction is directed toward reducing the odor level to a point below the threshold perception of the human nose. The human nose is the most sensitive analytical device known to mankind. Some of the more noxious odors are odors that are perceptible at a dilution of 1 to 10 parts per billion. Physiological and psychological reactions many times distort the perceptive impression of an odor. Most people object to any odor, pleasant or unpleasant, over a period of time. This marks the significant importance of a desirability of true odor counteraction. In the practical field of air pollution abatement in the past, the destruction of odors has often had the aspect of a hopeless task. The principle of odor counteraction provides a safe, proven, practical, and economical method of treating odorous air pollution from kraft mills. The method has been applied to digester relief and blow gases, evaporator vents, wet wells, building ventilation, and recovery stacks. Specific applications are discussed.

Chemical and Heat Recovery with the Venturi Scrubber at Thilmany, P. H. WEST

In 1946 pilot plant work conducted at Thilmany by A. W. Anthony, Jr., T. T. Collins, and H. F. Johnstone indicated that a considerable chemical saving could be achieved by scrubbing the kraft recovery unit stack gases with a liquid in a venturi scrubber. This pilot unit consisted of a venturi atomizer, using water as the scrubbing medium, and a dry cyclone.

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Based upon their findings, it was decided early in 1947 to install a full-scale water venturi scrubber to clean the gases from the existing 120-ton recovery furnace. In less than one year this equipment was designed, erected, placed in operation, tested, and paid for from savings.

Subsequently, further pilot plant studies were made in conjunction with the Babcock and Wilcox Co. but employing black liquor in the venturi atomizer. These test data indicated that such use of black liquor would improve the heat recovery efficiency over that of conventional kraft recovery systems while maintaining a high degree of chemical recovery.

The 120-ton unit and its water venturi scrubber continued to operate very satisfactorily until 1953. Then, because of increased pulp production and the demand for 600 p.s.i. steam, a new 250-ton kraft recovery unit was started. The new unit was installed with a venturi scrubber, using concentrated black liquor as the scrubbing medium, to recover both chemical and heat from the stack gases. Factors influencing the decision to use the venturi scrubber were (1) relatively low capital cost, (2) minimum space requirements, (3) trouble-free operation, (4) high chemical recovery efficiency, and (5) maxiumum heat recovery. The entire unit, in operation since May, 1953, shows chemical collection efficiencies of approximately 90%, as well as a considerable steam savings due to the more than conventional lowering of exit flue gas temperature. It has proved easy to operate, continuously available, and has required virtually no maintenance.

The Mechanism of Sulphate Pulping, G. R. Kulkarni and W. J. Nolan

The mechanism of sulphate pulping has been studied using slash pine chips, each 2.5 in. square, varying in thickness between 0.035 and 0.280 in. The effects of temperature, alkali concentration, and time on wood solution and delignification have been studied. From the data the equation,

$$\log (L - 3) = -(1 \times 10^{10})(10)^{-5250/T}\left(\frac{C}{76.5}\right)\theta + \log 97$$

has been drived, in which L = per cent of original lignin remaining, T = absolute temperature in degrees k, θ = cooking time in minutes, and C = concentration in grams of equivalent Na_2O per liter. The equation has been applied to the data of other investigators and has been found to give results which differ by a constant amount for each investigator's data. It is felt that differences in wood surface area, degree of mixing between chips and liquor, and liquor sulphidity may be largely responsible for deviations between calculated and observed data. In further studies, using slash pine cubes 2 by 2 by 2 in., liquor and lignin gradients across the wood sections have been established. From these data and phloroglucinal stained photomicrographs, evidence is presented which indicates that the pulping reaction is accomplished by the movement of a reaction interface which travels toward the chip center. The data show that the thickness of this reaction area, in which most of the delignification occurs, is relatively narrow. These observations were found to be true for blocks which had been pre-evacuated before cooking as well as for blocks which were cooked without pretreatment.

Total Pressures for the System: Sulphur Dioxide–Water, F. L. Wells and R. H. MacClaren

While commercial sulphite pulping is generally limited to a maximum sulphur dioxide concentration of 10% and pressures below 100 p.s.i., higher limits are not inconceivable, and are of interest for design and experimental purposes. Since previous investigation of higher concentrations has been confined to temperatures below 30°C. and higher pressures to a concentration of 6%, values have been determined for concentrations up to those of a two-phase system and at temperatures up to those corresponding to 150 lb. pressure.

The results of this investigation are compared with a previously reported statistical correlation. The minimum slope of straight lines drawn through the points on a modified Othmer plot does not agree with the statistically derived minimum slope. It is thought that the existence of a two-phase system at higher concentrations explains the difference.

Odor and Flavor Quality of Paper-Plastics Combinations, P. H. Kelley and L. C. Cartwright

Factors responsible for the growing importance of odor and flavor properties of paper-plastics combinations are reviewed. General and specific methods for determination of odor and flavor quality are presented, and examples of their application are given.

Combinations dealt with include plastic coatings on paper, plastic films laminated to paper, plastic laminating adhesives, plastic liners and overwraps, and additions of plastics to paper, in the beater or subsequently. Primary emphasis is on use in food packaging, but other applications are considered.

Properties of Latex Films Loaded with Inert Pigments, E. B. Osborne, R. D. Satava, and G. J. Antlfinger

In the practical use of latex normally two types of loading with inert pigments are encountered. The first type involves those applications wherein the quality of a continuous film is of prime importance and it is usually related to such properties as greaseproofness, gloss, and moisture vapor transmission of the finished coating. The second type is concerned with applications in which a discontinuous film is obtained, where the latex acts primarily as a binder or adhesive between the pigment and the substrate.

The paper industry is familiar with and utilizes both types of coatings in preparing their varied products. In general, the performance of a coating in the paper industry is judged by tests in which the substrate that is being coated frequently exerts a significant influence upon the results.

This paper is concerned with the changes occurring as measured by such physical tests as elongation and tensile strength when a free film of the latex is loaded with a variety of inert pigments covering both extremes of pigment loading.

New Developments in the Manufacture of Organic and Inorganic Synthetic Fiber Paper, H. F. Arledter

A number of new paper grades made of 100% organic synthetic fibers alone or in combination with inorganic fibers like glass have been developed.

Papers in which substantial amounts up to 100% of Dacron, Orlon, Nylon, acetate, and many other fibers are employed are described and suggested for special uses in plastic impregnation, as base for the laminating industry, for electrical uses, high-efficiency filtration, etc.

Application variables involved in such new paper materials are outlined with the discussion of such factors as selection of papers, strength, chemical inertness, thermal stability, shelf, dimensional stability, water pickup, etc.

Products with very good electrical properties and very high fire retardency are discussed.

Special absorbent paper grades with increased strength in laminates especially for low-pressure laminates will be described.

A Motion Picture Investigation of Polymer Latex Phenomena, John W. Vanderhoff

In the past, investigation of synthetic latex phenomena has been thwarted by the submicroscopic size of the latex particles. Particles smaller than about 0.5 mu are resolved only in the electron microscope. This limits observations to previously dried specimens. However, the greatest interest lies in the colloidal latex characteristics.

Recently uniform particle-size latexes ranging up to 1.5 mu have been prepared. Particles of this size are readily resolvable in the light microscope and thus the colloidal latex properties may be observed.

Motion pictures of various phenomena occurring in latexes have been prepared. These phenomena are: (1) Brownian motion of the latex particles; (2) convection currents in a drop of drying latex; (3) the packing of latex particles into a crystalline array at the edge of a drying drop; (4) spontaneous crystallization of latex particles (close-packed hexagonal array); and (5) "special" or novel effects.

The coagulation of latexes with added electrolyte has also been investigated. Increasing concentrations of electrolyte result in an increasing degree of flocculation of the latex particles.

The concentration effects of protective colloids on polymer latexes have been investigated. These include destabilization-stabilization at various concentrations. Protective colloids such as polyvinylbenzyl, trimethylammonium chloride, methyl cellulose, and casein have been considered.

Factors Influencing the Gas and Vapor Transmission of Polymer Films, V. T. Stannett

The permeability constant for gases and vapors through polymer films is made up of the product of the solubility coefficient and the diffusion constant. The effect of a number of gas and polymer properties on these two quantities is discussed and illustrated by practical data.

The Use of Polyamide Resin Suspensoids as Protective Coatings for Paper, Wilson F. Brown

The use of a polyamide resin suspensoid was studied as a coating for barrier-type food packaging paper. The raw stock for coating was glassine. The two main properties sought in the research were good oil resistance and low water vapor transmission rate. The coated paper resisted the penetration of peanut oil for a minimum of 1000 hr. at 73°F. and 50% R. H. even when a low weight of 2.8 lb. per ream was used. The water vapor transmission rate increased with increasing amounts of methyl cellulose which was used as a thickening agent. However, it was necessary

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to use a small amount of methyl cellulose in the suspensoid in order to obtain a good coated sheet. The water vapor transmission rate was found to decrease with increasing weight of coating, but after a coating weight of 18 lb. per ream was reached little change of rate was found. The addition of clay to the coating mixture aided in leveling the coating but caused an increase in the water vapor transmission rate.

Viscosity measurements were made on the suspensoid and coating mixtures with a Brookfield viscometer. It was necessary to control all conditions carefully to obtain reproducible results. The addition of the methyl cellulose caused the coating mixture to become thixotropic. The large effect of the temperature on the viscosities of coating mixtures made it necessary to control the temperature of the coating mixtures during coating operation.

The laboratory method of determining the coating weight is given together with factors causing possible errors. A constant speed laboratory knife coater is described and the method of operation is given. The coating was laid down as contiguous discrete particles, allowed to air dry and then fused at 250 to 300°F. for a short time to produce a continuous film of coating on the paper.

Physical Properties of Papers from Synthetic Fibers, James K. Hubbard, Franklin H. Koontz, and Robert A. A. Hentschel

The functional properties of the newer synthetic fibers, namely nylon polyamide fiber, "Orlon"* acrylic fiber, and "Dacron"* polyester fibers, their resistance to degradation by strongly corrosive chemicals, molds, bacteria, sunlight, heat, moisture, and their high strength, flex endurance, and abrasion resistance have prompted a study of their conversion into papers. Products with outstanding properties have been made on a laboratory basis. Measured on papers with a basis weight of approximately 60 lb. per TAPPI standard ream, papers from these fibers gave tenacities ranging from 22 to 33 lb. per in., elongation from 6 to 53%, Elmendorf tear strength from 298 to 1228 grams, bursting strength from 67 to 207 p.s.i., and MIT fold endurance from 51,000 to 1,000,000 cycles. The nylon papers can be sewn, with seam strengths equal to 40 to 100% of the base strength of the paper, depending on the way the seam is loaded. Heat seals of high strength can also be made on the nylon paper. Data are given on dimensional changes with changes in relative humidity. Bonding of the fibers to one another is the critical step in the preparation of these papers. The fibers are bonded either by the action of salts such as $CaBr_2$, LiBr, or $Ca(CNS)_2$, with synthenic polymeric binders such as *N*-methoxymethyl "Geon"† 576, or specially formulated polyamide and polyester adhesives. Methods used in the preparation and bonding of the papers are given. It is concluded that these papers represent potentially valuable products to further diversify the range of paper properties and that technological cooperation between papermakers and fiber producers will successfully solve the remaining production problems.

Pre-Mix Food Packages and Some Chemical Treatments to Reduce Penetration by Insects, H. E. Gray

During the last decade there has been a great expansion in pre-mix foods. To be acceptable the product must reach the consumer in an insect-free condition. To insure this the manufacturer must pack the product in a container that will be resistant to insect penetration during shelf life.

An analysis of the data accumulated by a leading manufacturer on the condition of his packages in retail stores showed that one package in 12 was infested.

Our success in preventing insect penetration of paper and cotton flour sacks through the use of piperonyl butoxide-pyrethrins mixture (Pyrenone) suggested that this material might be useful in increasing the resistance of pre-mix packages to penetration.

A series of experimental studies were set up to test the effect of surface application of Pyrenone with respect to concentration, amount, area, and method of application, as well as the use of Pyrenone in the adhensive. Studies were also made on the effect of testing with and without food.

The packages were tested in cabinets containing large stocks of stored-product insects. Samples were withdrawn at 2, 4, 6, and 8 months.

The packages were examined for insect infestation, entrance holes, and defects. The glue contacts were broken and the percentage of the flaps in close contact was estimated.

The higher concentrations of Pyrenone were toxic to the test insects. The lower concentrations apparently exerted a repelling effect although not directly proportional to concentration.

When the entire surface of the package was treated, protection was usually complete. When only part of the package was treated the results were variable.

The incorporation of Pyrenone in the glue used to form and seal the package increased the protection against penetration.

Food in the test chambers in general increased the degree of penetration. However, the effect varied with the test species as some penetrated more successfully without food.

Attempts to incorporate Pyrenone in varnish and lacquer coatings were unsuccessful.

Everban F 1001, a product containing Allethrin and an activator, afforded a high degree of protection but unfortunately this product imparted a distinct odor to the packages.

Some Factors Affecting the Laboratory Testing of Packages for Resistance to Boring Insects, David G. Edwards

The results of an extensive series of insect penetration tests on paperboard cartons treated with piperonyl butoxide-pyrethins are analyzed and possible correlations with field performance are discussed. In laboratory tests under continuous insect attack, the recommended dosage of this insecticide indicated limited resistance to penetration by cadelle larvae or adult saw-toothed grain beetles and lesser grain borers. In simulated shelf exposure tests with less insect pressure, fewer cartons were penetrated; however, the relative protection provided by the treated carton was no better. Before this type of accelerated laboratory test will be useful in predicting field performance, more detailed knowledge of field exposure hazards will have to be obtained.

Insect Repellent Coatings for Multiwall Paper Bags, Kenneth A. Arnold

Due to insect infestation, millions of dollars worth of food products have been condemned as unfit for human consumption by Federal inspectors. In flour products, the main sources of infestation appear to be in the grain, during the milling process, and through the package, during shipping and storage. Considerable progress has been made in treating the grain with nontoxic insecticides to prevent infestation at that point. Shortly after World War II an accelerated program of sanitation in the mills promised to eliminate infestation at that stage. Early in 1946, St. Regis became aware of a definite need for the development of a multiwall paper bag completely impervious to penetration by the flour-infesting insects, especially for shipment of flour into hot, humid areas favorable to breeding of insects.

Insects occurring most frequently in flour infestation include the cadelle, saw-toothed grain beetle, confused flour beetle, and the lesser grain borer. Tests on commercial 100-lb. flour bags in 1946 proved that the regular untreated multiwall paper bags were fairly resistant to insect penetration under normal conditions. Under severe infestation conditions, the untreated multiwall bag may be penetrated. Laboratory tests were started to determine the effectiveness of various insecticides against the infesting insects. After extensive laboratory evaluations, we found Pyrenone to be far more effective than other insecticides against flour-infesting insects under the conditions of treatments adaptable to multiwall bags. Pyrenone is a combination of two insecticides and is made up in the ratio of 10 parts piperonyl butoxide to 1 part pyrethrin. The piperonyl butoxide acts as a stabilizer and activator for the pyrethrin content. Laboratory tests indicated this ratio to be optimum and that a coverage of 50 mg. piperonyl butoxide per sq. ft. plus 5 mg. pyrethrin per sq. ft. was needed for effective protection against insect penetration.

In December, 1948, test bags comparing the various combinations of treatments with untreated bags were filled with sterilized flour at each of two well-known flour mills and shipped to two independent laboratories. In both laboratory tests, the filled bags were placed in steel chests and a large number of cadelles, confused flour beetles, or saw-tooth beetles were placed on top of the bags along with a small amount of flour for food. At the end of the 8-week period, the chests were opened and the contents of the bags sifted to determine the number and types of insects that entered the bags. The conclusions from the results obtained by the tests at both these laboratories were: the multiwall bags having the outer ply and sleeve coated with Pyrenone applied under commercial machine conditions were completely resistant to all the insects employed in these tests.

After the Pyrenone insecticide coating had been proved to be effective and commercially feasible, it was necessary to prove the Pyrenone to be of low toxicity in order to obtain approval for its use in bags to package products for human consumption. Permission was granted for the use of the desired coverage of Pyrenone as the outer surface on a multiwall paper bag for flour.

Two carloads of Pyrenone-treated multiwalls, freshly packed with flour, were infested separately with 3000 insects each, and shipped during August, 1949. At destination, inspection revealed all insects dead or paralyzed, with no penetration of flour.

Other factors covered in this development program included: (1) formulation and method of coating application at commercial speeds on paper machine, (2) stability of Pyrethrin component,

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Above: Beloit engineering conference: E. S. Skinner, Pat Patterson, Roy Martens

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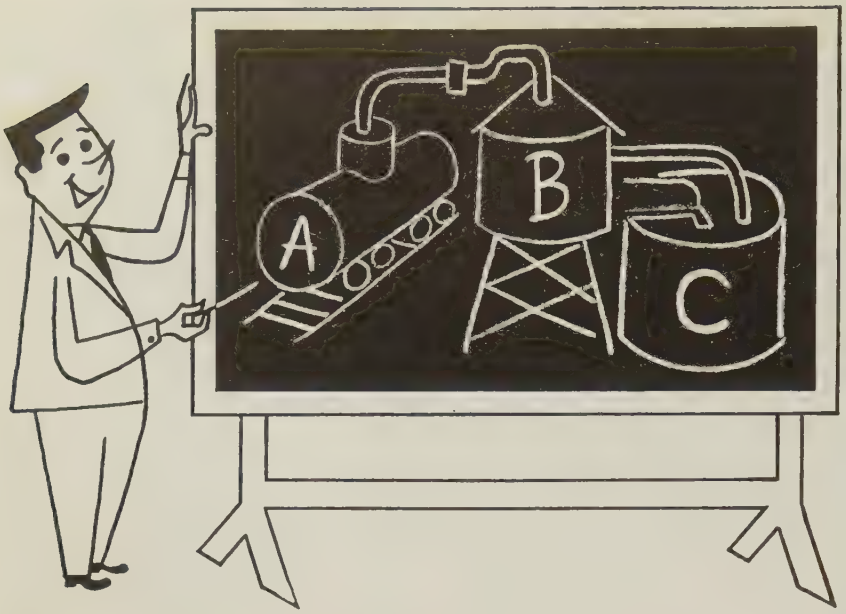

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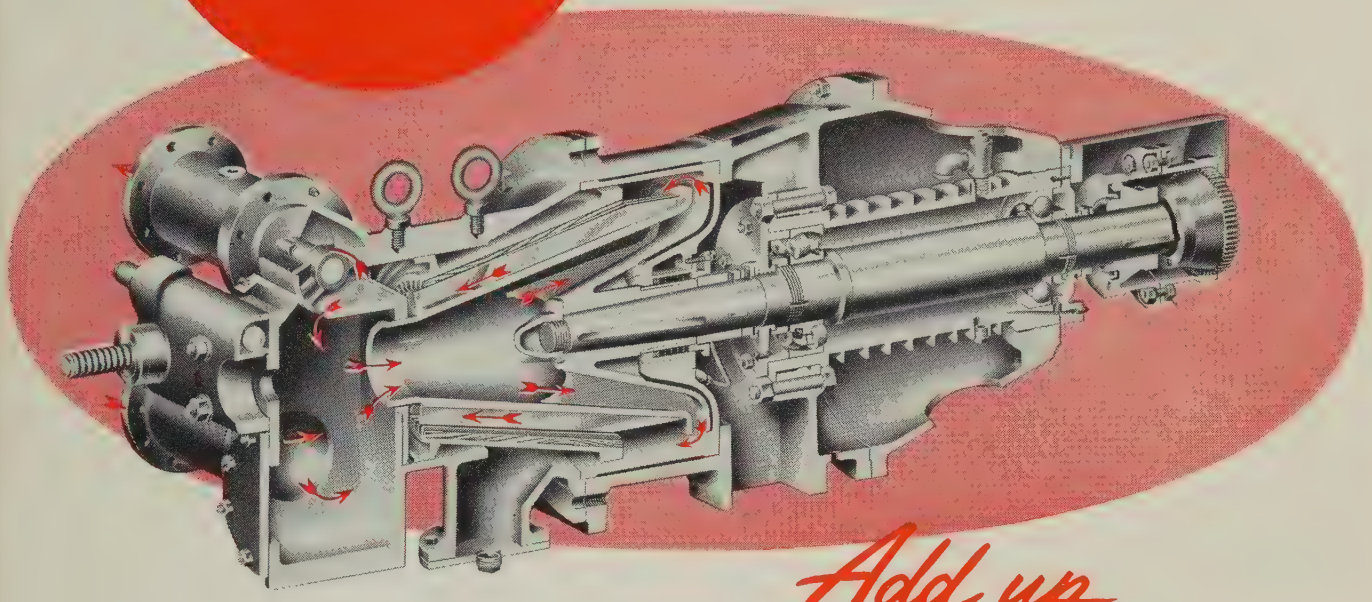

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(3) analytical methods for Pyrenone in paper coatings, and (4) comparative effectiveness of other insecticides now available commercially.

Insect Resistance of Fiber Containers, W. M. Van Horn

This discussion is general in nature and is designed to describe the problem and give background information helpful in understanding the other papers on the symposium.

There are, in general, two methods of preventing insect infestation of materials packaged in fiber containers. One method is to incorporate an effective physical barrier into the sheet and the other is to employ some sort of a chemical barrier.

There are inherent difficulties in using a physical barrier because, to be effective, this type of barrier must be kept free of openings large enough for insects or their larvae to pass through. Most often, in the fabrication of fiber packages a rigid physical barrier may be broken to the point of failure.

Most of the efforts, therefore, have been directed toward the objective of impregnating the sheet with a chemical that will either repel insect attack or kill the insects before they have a chance to penetrate the package.

One of the fields that hold promise is that of packaging cereal products. Among the insect adversaries in this field are the cadelle (*Tenebroides mauritanicus*), granary weevil (*Sitophilus granarius*), confused flour beetle (*Tribolium confusum*), saw-toothed grain beetle (*Oryzaephilus surinamensis*), lesser grain borer (*Rhyzopertha dominica*), the grain moths (*Sitotroga cerealella* and *Plodia interpunctella*), and the Mediterranean flour moth (*Ephestia kühniella*). The essential behavior pattern of each of these species is discussed in relation to the problem of fiber packaging.

The Status of Federal Research on the Development of Insect-Resistant Packages, Hamilton Laudani and Dean F. Davis

The cooperative research study between the U. S. Department of Agriculture and the Quartermaster Corps in the development of insect-resistant packaging which has been under way at the Stored-Product Insects Laboratory, Savannah, Ga., since 1950 has developed a sound appreciation of the important factors which influenced the improvement of packaging to this end. The study today has shown that: (1) paper bags appear to offer excellent possibilities for adaptation to insectproofing and from 9 to 12 months' protection can be expected with multiwalled paper bags having a synergized pyrethrum treatment applied on the outside ply; (2) lindane and methoxychlor appear to show great promise for possible use as protective coatings; (3) more effective insecticide treatments will have to be found if textile bags are to be made insectproof for periods extending over 6 months; (4) insecticide treatments on paper shipping boxes are not sufficiently effective to prevent insects from entering the package if open seams are present; to overcome this it is necessary to develop either boxes which are structurally more resistant to insect entrance or more effective insecticide coatings; (5) needle punctures on paper bags must be overtaped in order to obtain complete exclusion of insects and to derive the maximum benefits from insecticide treatments applied to the bags; (6) sleeve-valves are an important mode of entry for insects and it may be possible to design more effective folds for the sleeves to limit insect entrance; (7) the deposit of pyrethrum-piperonyl butoxide deteriorates rapidly when exposed to warehouse conditions but to a much less degree on rolled paper stored in darkness; (8) the greater part of the protection provided by the pyrethrum-piperonyl butoxide treatment can be explained on the basis of repellency rather than toxicity; (9) there exist several possibilities for the improvement of the effectiveness and duration of the pyrethrum-piperonyl butoxide treatment through the use of compounds which activate or extend the activity of the treatment; (10) it may be possible to substitute effective repellents in place of the pyrethrum treatment to accomplish the same end since the protection provided by synergized pyrethrum appears to be based on the fact that it repels stored-product insects.

A Laboratory Test for the Evaluation of the Repellency to Stored-Product Insects of Chemically Treated Paper, Hamilton Laundani, Dean F. Davis, and George R. Swank

A technique is described for the evaluation of the repellency to stored-product insects of candidate compounds when applied to paper. Briefly, the method consists of continuously exposing 10 adult flour beetles for 5 days on an arena composed of equal areas treated and untreated paper. Tests are run in quadruplicate with 10 insects in each replication, the insects being retained on the test papers by open-end glass cylinders. Comparisons of the repellent action of the experimental compounds are made on the basis of the number of insects counted twice daily on the untreated halves of the arena, and then taking the average of the 10 readings. A treated standard and an untreated check are included in each series for comparison.

During the development of the method, several tests were conducted to study and evaluate a number of the factors involved. The factors determined were: (1) the minimum convenient number of insects to produce significant results; (2) the minimum time lapse between introduction of the insects and the first reliable insect count; (3) the effect of changing the test insects daily on the reliability of the data; (4) the effect of light on insect distribution; (5) the expected deviation from the 50–50 response obtained in the insect counts over a 5-day period; and (6) the frequency of each numerical distribution.

The Development of an Insect-Resistant Folding Carton, R. I. Rice

Clay-coated folding cartons with the insecticide pyrethrins-piperonyl butoxide as the active ingredient of the clay coating have been shown to reduce infestation of stored products. The development of the carton involved a series of insectaria tests in which the effect of dosage level and coating formulation was evaluated by contact effect against *Tribolium confusum*. The starting point of the development of an insect-resistant carton was the treatment specified in the JAN specification P-137, Amendment 1, for multiwall sacks for overseas shipment. The variables studied were coat weight, diluent, and binder. Methoxychlor was tried in a limited number of experiments but Pyrenone was the principal insecticide evaluated.

The repellency of the insecticide is believed to be more important than its paralyzing or lethal effects and in the end it was shown that satisfactory reduction of infestation could be achieved at a dosage level which would be considered marginal in contact tests.

Before insect-resistant cartons can be accepted by the food industry it is necessary to determine that the Food and Drug Administration has no objection to the carton. In practice this determination is made by furnishing proof that the ingredients of the carton are not toxic and that there is no migration of chemical to the contents of the carton. Pyrethrins do not migrate but the synergist piperonyl butoxide does migrate. In three migration tests lasting from 6 to 12 months there was less than 1 p.p.m. of migration in the first two tests and up to 6 p.p.m. contamination in the third test. It is planned to present the results of the third migration test to the Food and Drug Administration in an effort to obtain acceptance of the treated carton. A partial solution to the problem of migration of piperonyl butoxide was found in a study of migration of butoxide from the clay coating to the boxboard filler.

Acceptance of the insect-resistant carton in the food industry will depend upon reduction in costs. The obvious solution to the economic problem would be the discovery of a cheaper insect repellent and toxicant. The author believes that the recommended dosage levels as determined in insectaria studies are too high and that a satisfactory reduction in infestation in food cartons will be found at more economical dosages.

Recent Developments in the Use of Chemical Treatments and Synthetic Fibers in Paper Machine Felts, L. M. Woodside

It is often difficult to make a felt which will have correct strength for good operation, correct openness for efficient water removal, and correct fineness for desired finish. The introduction of chemical treatments and synthetic fibers in many cases has helped this situation.

We have run tests in our laboratory on practically every synthetic that has been developed. There are only a few which to date have proved to be of value for practical use in felts. However, something in the neighborhood of 40% of our felts contain some synthetic fibers. Where synthetic content felts are suitable, life has sometimes increased from 25 to 50%, occasionally more. Their major benefits are increased strength and resistance to frictional wear.

Benefits sometimes achieved from the added strength and resistance to wear include: better openness, because of being able to get proper strength in a lighter, more open felt, and improved finish because of being able to use smaller yarns yet gaining the needed strength by using a synthetic.

However, a synthetic content felt is a harder felt than an all-wool felt. This hardness can be reflected in poorer water removal, more crush marks or yarn marks, or poor drying. Chemical treatments often can be used to correct these conditions.

Chemically treated felts preceded the use of synthetic fibers, and treated felts are still often made without the addition of synthetic content. We now have treatments which will make felts resist the action of alkalies and bacteria, will improve their ability to remove water, maintain their softness and openness, improve wear resistance, and resist the action of certain paper-making chemicals.

Our J-3 treatment makes a felt retain its softness and openness for a longer period of time, and imparts resistance to the action of some chemicals. By allowing a synthetic content felt to operate more efficiently for a longer period, it permits taking the full benefit of the synthetic's resistance to frictional wear.

These materials have their places in our industry but we also feel that the basic felt design must be correct before the treatment or the synthetic can do the job expected.

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Algin Use in Board and Liner Manufacture, A. L. Magnuson and H. W. Bartlett

This paper is a résumé of the field experiences of the paper technical staff of Kelco Co. in the application of algin to board and liner manufacture and conversion. The functions of algin are basically those of film forming, solids suspension, emulsion stabilization, and viscosity development and control.

The purposes for which it is used are described as providing the required surface conditions for all types of printing, for finish and smoothness improvement control, density increase to almost any desired point, uniform and efficient holdout of waxes, varnishes, and solvents, water, blood, grease and scuff resistance, modification of many types of coating to provide various desired end effects, and addition at the wet end for increased strength characteristics, stiffness, smoothness, brightness, density, and improved printabilities.

The grades of board and liner on which algin is used are bleached and unbleached kraft and sulphite, both cylinder and fourdrinier, patent coated, bleached Manila, various vat lined and various test and nontest liners.

Formulas, methods, and points of application, as well as detailed result statistics are described. Means of building high printability, density, and wax holdout on such grades as milk bottle, frozen food, and many other folding grades are described with appropriate result and cost data. A practical method is presented for suspending successfully pigments and other materials for application at the size press or calender stacks. Scuff resistance, grease, and water resistance are discussed and field experiences noted.

In the coating field, the incorporation of algin is explained and evidence is shown of better solid suspension, reduction in pigment flotation, control of binder migration into the web, and reduction of cost. This takes in the packaging as well as building grades.

The wet end addition of algin, either alone or in combination with other commonly used materials is discussed. Data from research projects and regular commercial production are presented. These indicate increased density and fines retention, higher printabilities, and improved strength characteristics, particularly in stiffness. Formulas, methods of incorporation, and cost figures are outlined.

An Evaluation of Various Beater Retention Aids for Titanium Dioxide Filler in the Presence of Chlorinated Cornstarch Harold C. Brill

Data based on laboratory handsheet evaluations are given to show that most commercial cornstarches for beater addition are harmful to titanium dioxide retention. Chlorinated cornstarch was found to be one of the most harmful. Paper manufacturers encounter chlorinated cornstarch in their beaters because it is added for bursting strength improvement, from coated paper broke or wastepaper addition. The effect of basis weight, preflocculation of pigment, alum, sodium aluminate, sodium phospho aluminate, animal glue, diatomaceous silica, Idaho potato starch, and cationic starch on the retention of titanium dioxide in the presence of chlorinated cornstarch is evaluated. The data indicate that most of the retention aids lose much of their value in the presence of chlorinated cornstarch. Under the conditions of the test, sodium phospho aluminate and cationic starch gave the best results.

Determination of Carbon Dioxide by Conductivity Measurements, C. A. Noll and J. W. Polsky

In the field of industrial water conditioning, there is need for a rapid and precise method of determining the carbonate content of deposits formed in water systems. Carbon dioxide in different materials can be determined by a variety of methods.

A method has been developed for the determination of carbon dioxide which is applicable to analysis of waterside deposits, treatment chemicals, and organic carbon in water. The principle of differential conductivity permits rapid, accurate analyses.

Technical Manpower and Technical Information, T. T. Collins, Jr.

A discussion of the so-called "shortage" of trained scientists and engineers in the United States and figures for the number of technicians being trained in Russia as compared to the United States are given. The various aspects of the deployment of technical people in Russia by the government are mentioned. As a means of increasing the effectiveness of technical personnel now employed in industry, various matters relative to adequate mill libraries and their use are outlined. Data are given to illustrate the number of patents and articles abstracted each year in the field of chemistry and related subjects. Various recommendations are made for simplifying and broadening the coverage of the papermaking literature and the Microcard system for photographic reproduction of the literature is discussed.

A Rapid Method of Estimating the Titanium Dioxide Pigment in Paper, Harold C. Brill

Certain beater additives have a marked effect on titanium dioxide retention and this property may vary widely in mills returning coated paper broke to the beater. This indicates the need for regular and systematic analyses of the paper production for titanium dioxide content to prevent loss. The present titanium dioxide analyses methods are time consuming and require personnel with skill in analytical chemistry. A method is needed that is rapid and simple and can be performed by the regular mill employee in 15 min. or less. The method need not be as accurate as present analyses and might be considered an estimation. A simple method of estimating the titanium dioxide pigment content of a paper from the opacity of a waxed or oiled sheet is discussed in this paper. This test is designed to supplement the existing analytical methods and is not intended as a replacement.

An experimental procedure is presented showing the best method of waxing or oiling a sheet of paper so that complete saturation is secured. The method of preparing standard waxed opacity—TiO_2 content curves is explained and their use is discussed. Data are presented indicating that such curves must be prepared for different basis weights of paper. It was discovered that the method was suitable for titanium dioxide in the presence of clay or with papers containing a high content of groundwood. Brightness variation of 20% caused a waxed opacity change of only 2%. Saturation curves are shown for both paraffin wax and mineral oil for a lightweight bread wrap sheet, and the relative merits of each as a saturating medium discussed. A study of 13 determinations is included showing the relative error to reach a maximum of $\pm 10\%$ and an average error of about 5%.

Vat Exhauster Survey, Otis R. Witworth

With the higher machine speeds and quality standards that have been achieved in recent years, there have been some operating difficulties that had to be overcome in the formation of the sheet on the mold. Some of these problems were overcome by the use of exhauster systems. The pressure differential applied across the face of the mold not only helps prevent slippage and rain, but also helps produce a tighter and more even sheet, removes more water, and gets rid of foam inside the molds. The major disadvantage being a slightly greater tendency toward wrapping the mold.

The design of an exhauster system requires that careful consideration be given to all of the various components. Present-day practice indicates that a vacuum of 0.75 in. to 1.5 in. of water is required in the mold and sufficient air must be handled to produce this vacuum. The amount of air varies under different conditions from 250 to 500 cu. f.p.m. per ft. of mold face.

Pipes should be sized to give reasonable velocities in the vicinity of 3500 f.p.m. and the pressure drops through the pipes calculated. It is very important that the static pressure rating of the fan is not chosen too low, which seems to be a common fault of existing systems. There are several different types of systems and which one is used is mainly dependent on economics and local mill conditions.

Stock Cleaning Systems, P. S. Bolton

This paper points out the importance of increasing the use of waste paper, which has steadily declined since 1946 in its ratio to total production. The increase in paper and paper board production has been much greater in container board than in the higher grades so that if more waste is to be reworked it must come from these grades.

It is contended that by utilizing standard equipment now on the market these lower grades of waste paper can be reworked to produce pulps equivalent to hardwood semichemical pulps. This equipment must be designed into an integrated system handling the paper so that the various types of dirt are progressively removed. The cleaned pulp can be bleached by standard methods.

Properties and Analysis of Inorganic Pulping Solutions, S. T. Han, J. L. Davis, R. B. Kesler, and R. S. Couceiro

The physical and chemical properties of a pulping solution are essentially those of the electrolytes constituting the solution. The distribution of the ionic species present in the aqueous medium and its bearing on chemical analysis are discussed with respect to the equilibria involved. Solubility and density information on the common pulping solutions are reviewed, and new data are presented.

The conventional analysis of pulping solutions is based on two basic chemical techniques: acidimetry and iodometry. The application of these two methods to the most complex system, a recovered neutral sulphite cooking liquor, serves to illustrate their reliability and limitations.

Suggestions are offered for the redefinition of some of the important characteristics of pulping solutions, to extend their range of usefulness and to avoid ambiguity.

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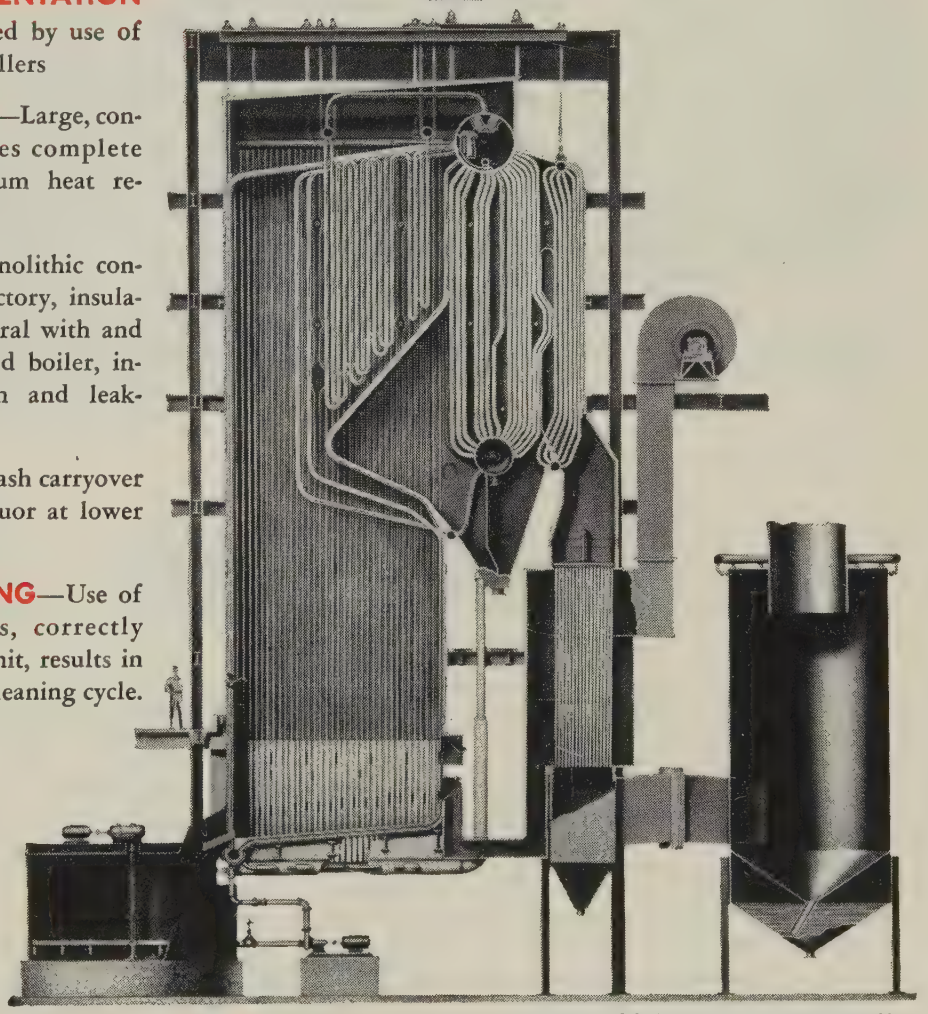

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New York 17, N. Y.

P-780

Many of the popular magazines on American newsstands are made economically possible, in large part, by "Virginia" Zinc Hydro.

"VIRGINIA" ZINC HYDRO

Produces Bright Pulp at Low Cost

Brand new techniques for the reduction-bleaching of groundwood pulp with "Virginia" Zinc Hydro are piling up profits for pulp mills.

This powerful reducing agent does a comparable job at about one-half the cost of oxidizing bleaches.

Here are some of the actual results recently reported:

- "A 12-point brightness increase."
- "Per ton costs have never exceeded 60c per brightness-point."
- "We have saved as much as $8 per ton."
- "Brightness permanence is equal to other bleaching."

The "Virginia" Zinc Hydro process with its economies in time and efficiency applies to the big and little mill alike. Almost no new equipment investment is needed; fewer chemical additives are required. Chemically, "Virginia" Zinc Hydro is stable in storage. It is free-flowing, non-clogging and non-corrosive.

A competent, experienced Virginia engineer will be glad to discuss these new developments at your plant—just tell us when you'd like to have him come. **Industrial Department, VIRGINIA SMELTING COMPANY, Dept. 77-P, West Norfolk, Virginia.**

VIRGINIA Chemicals

Field Offices: NEW YORK • BOSTON • DETROIT
CHICAGO • ATLANTA • ASHEVILLE
Available in Canada and many other countries

Monel shower tube has non-plug type nozzles soldered on at plant of A. E. Broughton & Company, Glens Falls, N. Y. Broughton uses Monel because of its excellent resistance to corrosion by white water and its high rigidity, which allows long unsupported tubes.

Use Showers? Look at this one

Monel to prevent clogging and sagging

There'll be fewer problems on the paper machine that gets this Broughton self-cleaning white water shower.

It takes but a moment to see why...

The design is uncomplicated. All parts are precision built. A cleaner unit in the nozzle tube is reversed by a 4-way valve, scraping dirt and stock from nozzles and tube, and discharging to gutter.

And have you noticed the nozzle tube and the return tube? *Both are made of Monel®.*

If you're using Monel anywhere in the mill, you're probably familiar with the outstanding characteristics of this versatile Inco Nickel Alloy.

You know, for example, that Monel is stronger and tougher than mild steel. That it withstands wear and abrasion. That it stubbornly resists corrosion by white water, caustic liquors and alkaline cleaning solutions. That it has the rigidity necessary to prevent even a long shower tube from sagging.

You understand then why Monel outlasts conventionally used nonferrous metals . . . how it contributes to fast, improved production . . . how it helps you hold maintenance costs within reasonable limits.

Put Monel to work for you in showers, too. Write *A. E. Broughton & Company*, Dept. M, Glens Falls, N. Y., and ask for their catalog, *Broughton Systems for Paper Machines.* The company offers a full line of stationary and oscillating fresh and white water showers for cleaning Fourdrinier wires, dandy rolls, cylinder moulds, savealls and other machines. All, of course, are made with Monel—to serve you better.

You yourself can specify Monel for fluid filters, stock lines, doctor blades, head boxes and slices. Or Inconel® for pulp digester lining and cladding. These Inco Nickel Alloys give you superior resistance to corrosion...extra-long life . . . extra-good performance.

So don't wait. The sooner you start using Inco Nickel Alloys, the sooner you'll have fewer problems on *your* machines.

For answers to corrosion problems anywhere in the mill, write to our Corrosion Engineering Section.

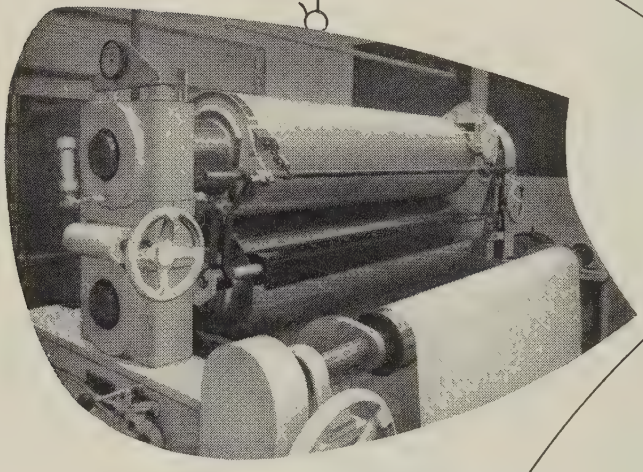
The International Nickel Company, Inc.
67 Wall Street New York 5, N. Y.

INCO TRADE MARK **Nickel Alloys**

Monel...*for minimum maintenance*

Still another installation by a leading producer demonstrates the advanced planning and efficiency of Frank W. Egan & Company design. This TREATER was chosen to produce Formica laminated sheets for decorative and industrial applications because it turns out the highest percentage of perfect material and treats the base stock *uniformly*. An Egan exclusive is the micrometer gauge for exact control and finest adjustment *while operating*.

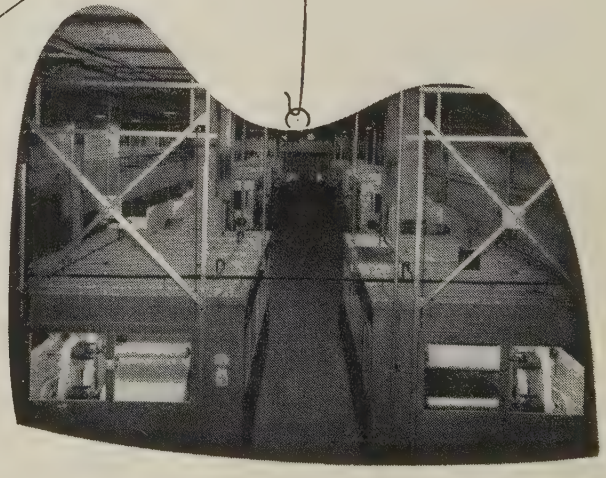
Egan



Treater

FOR LAMINATED PLASTICS INDUSTRY

The Formica Company, Cincinnati, O., has installed three Treaters in two of their plants.



Egan
FRANK W. EGAN & CO.
BOUND BROOK, N.J.

for full information write

FRANK W. EGAN & COMPANY

Bound Brook, New Jersey

Designers and Builders of Machinery for the Paper Converting and Plastics Industries

Cable Address: "EGANCO"—Boundbrook, N. J.

REPRESENTATIVES:—ACHARD-PICARD, REMY & COMPANY, PARIS • BONE BROTHERS, LTD., LONDON • H. W. GOTTFRIED, MEXICO CITY
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First H_2SO_4 ... by General Chemical, the nation's primary producer of Sulfuric Acid.

then SO_3 ... by General Chemical, the country's sole source of Stabilized Sulfur Trioxide

...Now SO_2 by General Chemical

LIQUID SULFUR DIOXIDE

WITH THE ADDITION of Sulfur Dioxide to its extensive line of basic chemicals, General Chemical now becomes industry's *sole source* of all three key "sulfur" chemicals.

TO THE MANUFACTURE of SO_2, General brings its tremendous knowledge of sulfur chemistry, gained as America's pioneer producer of Sulfuric Acid by the contact process and as the only producer of "Sulfan"*—Stabilized Sulfur Trioxide.

THIS MANUFACTURING and technical background is reflected in the extremely high purity of General's Sulfur Dioxide which assays 99.9% SO_2 . . . and stands as your guarantee of another of the many first-rate "GC" Basic Chemicals for American Industry.

IF YOU ARE READY to place an order for your current SO_2 *tonnage* requirements, call in General—the company that is known throughout the country as first for Sulfuric Acid and related chemicals. Just phone or write any of the 27 General Chemical offices listed below for full information.

Packaging

1 Ton Containers
Multi-Unit Cars (15 one-ton cylinders)
Single Unit Tank Cars (18 and 36 Tons)

Specifications

Assay	99.9% SO_2
Molecular Weight	64.06
Melting Point	—103.9°F (—75.5°C)
Boiling Point	14.0°F (—10.0°C)
Specific Gravity	1.363 at 80°F
Critical Temperature	314.82°F (157.12°C)
Critical Pressure	1141.5 p.s.i.a.

Typical Uses of SO_2

Preparation of hydrosulfites, sulfoxylates and other chemicals; as a bleaching agent in textile, paper, clay and leather industries; refrigerant; as an antichlor for use in water treatment, textiles, paper and other plants where chlorine has been used; in the processing and preserving of food products; in petroleum refining; for treatment of chromium waste liquors.

*Reg. U.S. Pat. Off.

GENERAL CHEMICAL DIVISION
ALLIED CHEMICAL & DYE CORPORATION
40 Rector Street, New York 6, N. Y.

Offices: Albany • Atlanta • Baltimore • Birmingham • Boston • Bridgeport • Buffalo Charlotte • Chicago • Cleveland • Denver • Detroit • Greenville (Miss.) • Houston Jacksonville • Kalamazoo • Los Angeles • Minneapolis • New York • Philadelphia Pittsburgh • Providence • San Francisco • Seattle • St. Louis • Yakima (Wash.)
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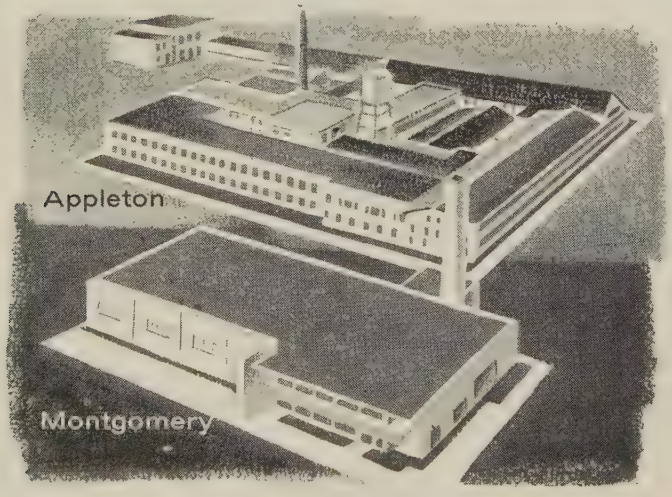
GC Allied Chemical

Basic Chemicals for American Industry

How paper helps market the wares of the world



General Offices, Appleton, Wisconsin

Plants at Appleton, and Montgomery, Alabama.

From producer to consumer, paper for packaging is a vital and rewarding link . . . ambassador of good will and good deeds . . . preventing costly spoilage or damage to everything from foods to machinery, clothing to crockery . . . upgrading quality and appeal . . . building sales of goods and services everywhere.

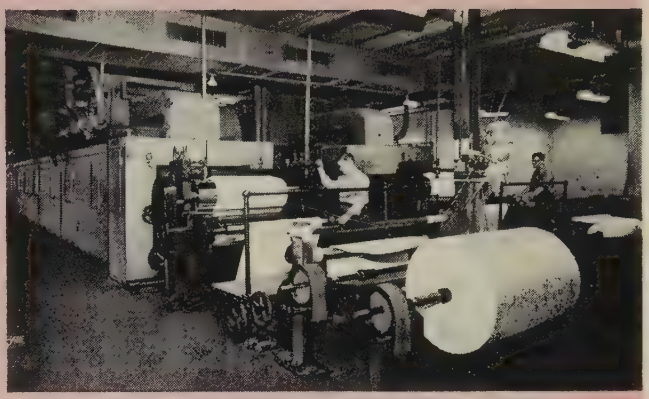
And in at the very start of packaging paper—in every field where paper goes to work . . . Fourdrinier wires. Appleton Wires. Good wires—by a 59-year test of industry-wide acceptance and use.

Appleton Wire Works, Inc.

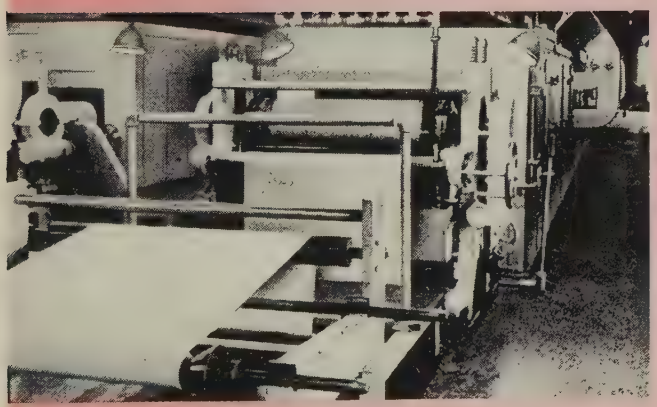
Appleton, Wisconsin

Let WALDRON solve your Converting problems

You will benefit from WALDRON's longer experience in meeting particular requirements for greater processing SPEED and ACCURACY, less SPOILAGE of material, reduced COSTS for equipment OPERATION and MAINTENANCE. You don't experiment when you deal with WALDRON.



WALDRON units used for coating and impregnating paper base materials at Mica Insulator Company.



WALDRON equipment used in treating plastic fillers in plant of Continental-Diamond Fibre Company.

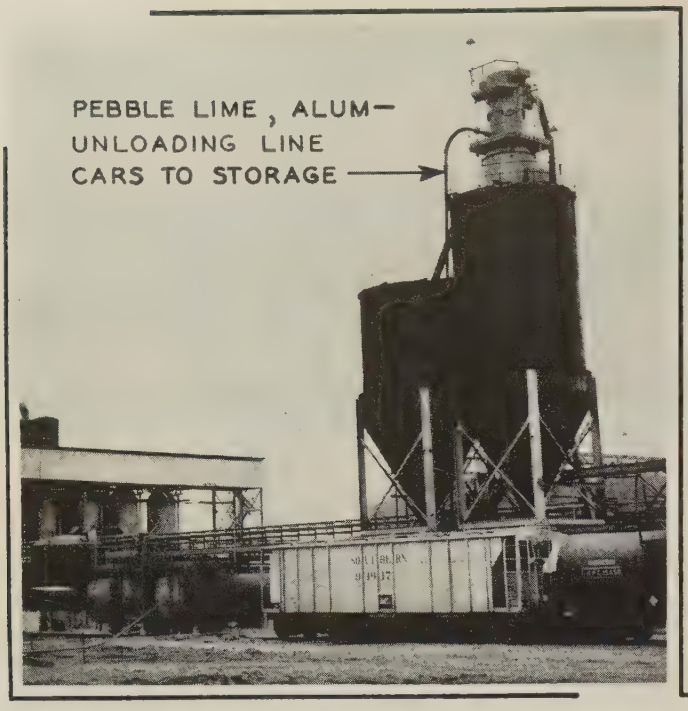
With their unequalled research, engineering and manufacturing facilities available to them, WALDRON engineers are in a position to meet your requirements at minimum expenditure of your time and money. The impressive number of users of WALDRON equipment is ample proof of that.

Write for bulletins describing the type of converting machinery in which you are interested.

John WALDRON Corporation

P. O. BOX 791 · NEW BRUNSWICK · NEW JERSEY

Leaders In Web Process Engineering Since 1827



flow your bulk chemicals

like Buckeye Cellulose *does with* The AIRVEYOR®

Once again, the Airveyor goes into service in the pulp and paper industry—this time in the 25 million dollar plant of the Buckeye Cellulose Corporation, Foley, Florida, subsidiary of the Procter & Gamble Company. This thoroughly modern plant has a capacity of 300 tons of dissolving cellulose pulp per day.

Incoming mill-supply chemicals are handled by two Airveyor conveying systems. One system unloads salt cake from box cars and delivers to a storage bin at rate of 10 tons an hour. The same system also conveys from a pulverizer discharge and delivers to a service bin in the recovery building. The second Airveyor unloads alum and pebble lime from either box or hopper-bottom cars and delivers to a storage bin at rate of eight tons an hour.

The pulp and paper industry has learned by experience that Fuller Company is able to engineer and build equipment that will serve them for many years, at the lowest operating and maintenance cost. This is attested to by the many satisfactory installations in operation. Individual company purchases range from one to as many as twelve systems.

You should get all of the facts on the Airveyor. This specialized system, developed by Fuller, with many years of experience in conveying with air, can save you many a dollar, day in and day out. Why not have a Fuller engineer make a study of your conveying problems—it will cost you nothing.

FULLER COMPANY
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FULLER COMPANY, Catasauqua, Penna.

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DRY MATERIAL CONVEYING SYSTEMS AND COOLERS . . . . PREHEATERS . . . . COMPRESSORS AND VACUUM PUMPS . . . . FEEDERS

®BECCO H_2O_2

Use BECCO Pulp Dryer Steep Bleaching for chemical pulp superbleaching or prevention of brightness reversion

You can get selected brightness grades from a single pulp. You can change grades at will without accumulating transition pulp. You super-bleach to the 85-90 brightness level. You overcome brightness reversion of baled pulp due to aging during storage and/or shipment.

You can use your regular pulp dryer to do this job, whether you have Fourdrinier or vacuum cylinder, wet ends or hot air or can drying equipment.

The Becco Pulp Dryer Steep Bleaching process with Hydrogen Peroxide is primarily applicable to bleached or partly bleached sulfite, kraft or soda pulps. Ask to see Becco technical consultants or send for Bulletin D-8 with complete description of process, typical mill results on various pulps, schematics of process equipment, production chart and other helpful information.

Other Becco paper industry processes are described in the following bulletins: D-1 Becco Methods for Soda Pulp Bleaching, D-2 Becco Peroxide Bleaching Methods for Sulfite Pulps, D-3 Becco Procedures for Bleaching Kraft Pulps, D-4 Data on Flax Pulp Bleaching, D-5 Becco Peroxide Bleaching Methods for Semichemical Pulps, D-7 Becco Pulp Bleaching with Mixed Peroxides, D-10 Pretreatments for Groundwood Pulps, D-11 Becco Peracetic Acid 40% for Applications in Pulp and Paper Mills, D-12 Starch Solubilization with Becco Potassium Persulfate, D-13 Bleaching of Groundwood Pulp with Hydrogen Peroxide, D-14 Becco Hypochlorite-Peroxide Bleaching Process. *Write for complete bulletin list or any of the above.*

BECCO CHEMICAL DIVISION

FOOD MACHINERY AND CHEMICAL CORPORATION

STATION B, BUFFALO 7, N.Y.
BUFFALO • BOSTON • CHARLOTTE • CHICAGO
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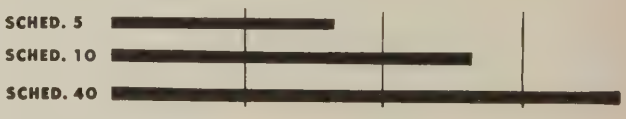
when you need STAINLESS PIPE...

look at all 3

Here's A Cost Comparison on All Three



Here's How All Three Compare in Weight

To get the most economical stainless pipe for handling corrosive fluids, Schedules 5, 10, and 40 should be closely compared for:

initial cost
installed cost
ease of handling
flexibility of assembly
flow capacity
adequate allowable working pressure
effective corrosion resistance
service life

Whichever Schedule—5, 10 or 40—is best for your service conditions, Carpenter makes it to meet ASTM pipe specifications. Carpenter Stainless Pipe is available in sizes up to 4 inches, depending on weight . . . in AISI stainless analyses plus Carpenter Stainless No. 20 Cb, and Carpenter Alloys B and C for super corrosion resistance. For services requiring extra smooth surfaces, Carpenter Stainless Pipe can be supplied with 80 to 320-grit polished I.D. and/or O.D. finishes. Adequate stocks are as close as your local distributor. Call him for information and time-saving delivery.

The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

Export Dept.: The Carpenter Steel Co., Port Washington, N. Y.—"CARSTEELCO"

Carpenter

more than corrosion resistance

Stainless Tubing & Pipe

For wet strength in a hurry—UFORMITE 700

UFORMITE 700 gives your paper high wet strength fast. In almost any kind of furnish—bleached or unbleached kraft, sulfite, or groundwood—you get high strength right off the machine.

UFORMITE 700 has other important advantages: *Highly efficient*—provides effective results over a wide range of resin-to-pulp ratios. • *Easily mixed*—no acid pretreatment, no special equipment needed. • *Simply controlled pH*—acid, alum, or blends of both can be used. • *Conveniently added*—at any desired point from beater to headbox. • *Long storage life*—the stability of UFORMITE 700 helps eliminate inventory problems.

Other Rohm & Haas chemicals for the paper industry include hydrosulfites for bleaching wood pulp; resin emulsions for paper coating and saturation; surface-active agents, pitch dispersants, deodorants, and bactericides.

CHEMICALS FOR INDUSTRY

ROHM & HAAS COMPANY

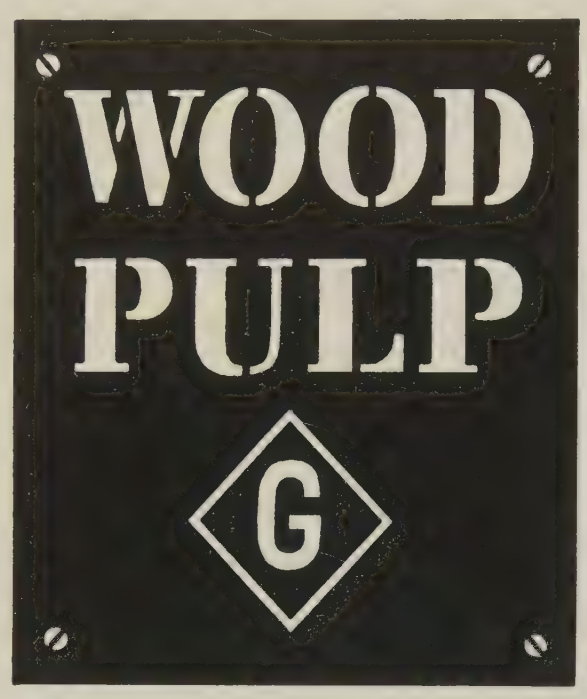
THE RESINOUS PRODUCTS DIVISION

Washington Square, Philadelphia 5, Pa.

Representatives in principal foreign countries

UFORMITE *is a trade-mark, Reg. U.S. Pat. Off. and in principal foreign countries.*

Established 1886



"The result tests the work."
WASHINGTON

How shall we measure the scope and meaning of the Pulp and Paper Industry, except by the ultimate uses of paper? It carries information to the four corners of the earth, makes possible the complex operations of modern business and government, and year by year adds new convenience to every American household.

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GOTTESMAN & COMPANY

— INCORPORATED —

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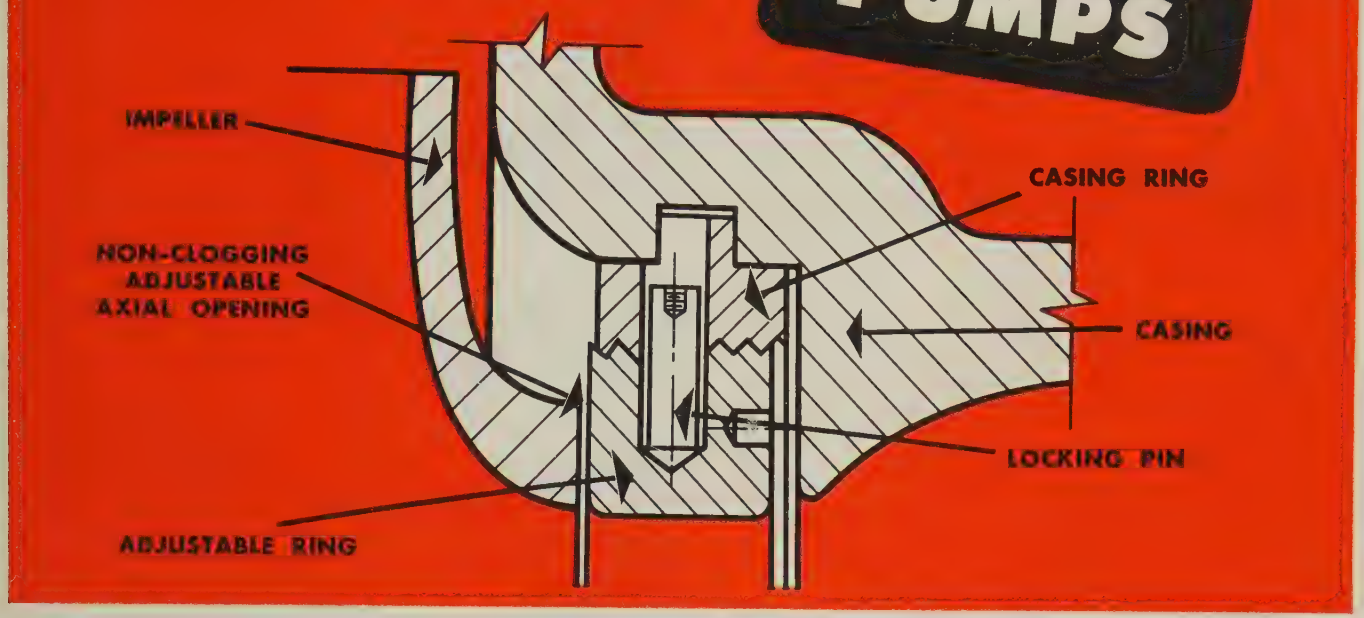
EUROPEAN OFFICES: Birger Jarlsgatan 8, Stockholm, Sweden

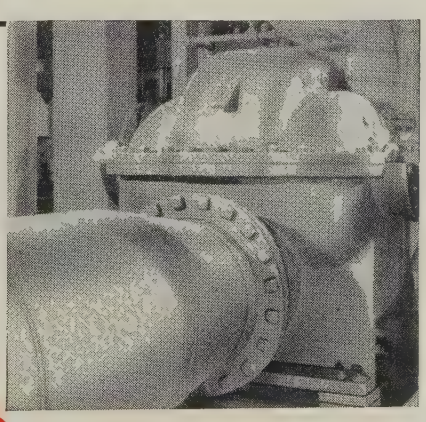
ALLIS-CHALMERS
Double Suction
PUMPS



This wearing ring design pays off in Long Life... Low Maintenance

- ***You can compensate for wear***
- ***. . . eliminate seizing damage***

This unique Allis-Chalmers pump design features adjustable clearance wearing rings with an *axial* rather than a *radial* opening. It will cut your pump costs by keeping efficiency high in spite of wear and by preventing damage due to seizing of impeller by stock in the wearing ring clearance. Ideal for fan pump, white water, light stock, or small solids in suspension.



This 24 by 24 Type SK, 15,000-gpm, 30-ft head fan pump moves stock from wire pit to machine head box at Potlatch Forests, Inc., Lewiston, Idaho.

A-4424

To Adjust Clearance for Wear

Remove pin, turn threaded inner ring until clearance is correct, replace the pin. Correct clearances not only keep efficiency high but tend to exclude solids and eliminate clogging.

Radial Clearance Prevents Seizing

Wearing rings on Allis-Chalmers pumps have axial clearance; thus solids work themselves free. And — the temporary added load on the thrust bearing causes no trouble because the bearing is built big enough to take it. In pumps having ordinary wearing rings, with radial clearance, solids wedging between the ring and impeller may deflect the shaft — cause the impeller to seize.

Stainless steel wearing rings are carried in stock for 16 by 14 and smaller-sized pumps.

★ ★ ★

See how these and other features keep pump costs down. Find out, too, why it pays to specify Allis-Chalmers for the complete pumping unit — pump, motor, drive, and control. Contact your district office or write Allis-Chalmers, Milwaukee 1, Wisconsin. Ask for bulletins 08B6146, 52B7112 and 52B7839.

A-C ALLIS-CHALMERS

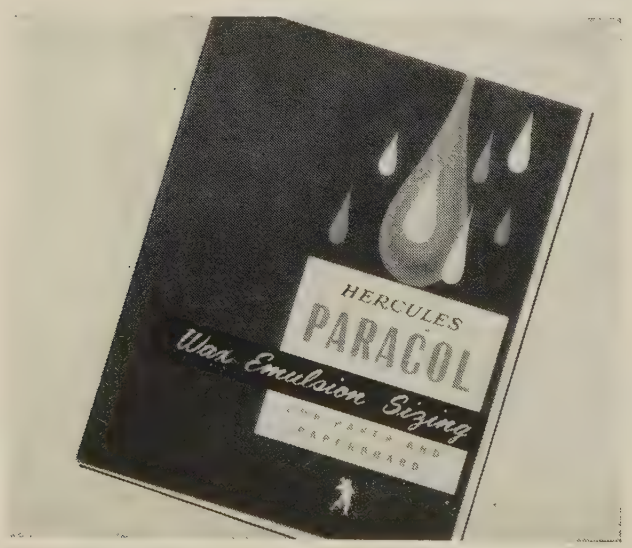
ALLIS-CHALMERS

BETTER PAPER THROUGH HERCULES CHEMICALS

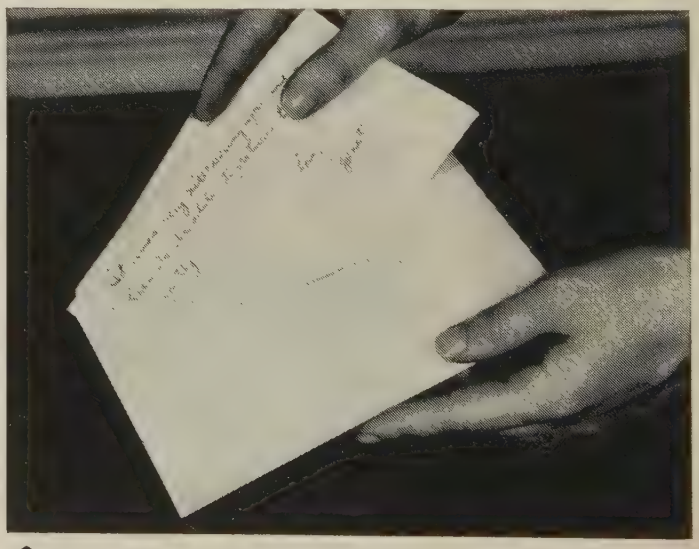
More than a dozen types of Hercules Paracol® wax emulsions, each developed in Hercules laboratories to solve some specific type of sizing problem, are improving performance while effecting economies in size furnish for paper and board mills from coast-to-coast.

The wide range of Hercules Paracol wax emulsions and the diversity of their applications indicate the many opportunities Hercules papermaking chemicals offer to improve your products and reduce your costs. Contact your local Hercules technical representative or write directly to Hercules for descriptive literature.

LIQUID REPELLENCY—In surface sizings, the addition of small quantities of Paracol at the calender stack or size press improves liquid repellency and printability of paperboard.



TECHNICAL DATA—This descriptive booklet containing technical data on all types of Paracol can be obtained by writing Hercules for your copy.



IMPROVED QUALITY—One or more of the Paracol wax emulsions are used for fold properties of envelope papers, improving finish and creasing properties of many types of paper and board.

Paper Makers Chemical Department
HERCULES POWDER COMPANY
INCORPORATED
967 King Street, Wilmington 99, Delaware

PP54-9

and **NOW**

in **GRIFFIN**

A ***NEW*** Stowe-Woodward rubber roll covering plant . . . all new . . . and designed from the ground up for the manufacture of rubber covered rolls exclusively.

Here in Griffin . . . in the heart of the expanding Industrial South . . . are complete facilities for every stage of manufacture, from raw rubber to finished roll, including the big rolls of today, and the bigger ones of tomorrow. Like Stowe-Woodward's Neenah Plant . . . opened less than 8 months ago . . . this new southern plant is part of a program planned to bring closer to the industries it serves, Stowe-Woodward's

"Rubber Rolls with a Reputation"

S-W INC.

STOWE-WOODWARD, Inc.

Craftsmen in rubber rolls

NEENAH, WISCONSIN — NEWTON 64, MASSACHUSETTS — GRIFFIN, GEORGIA

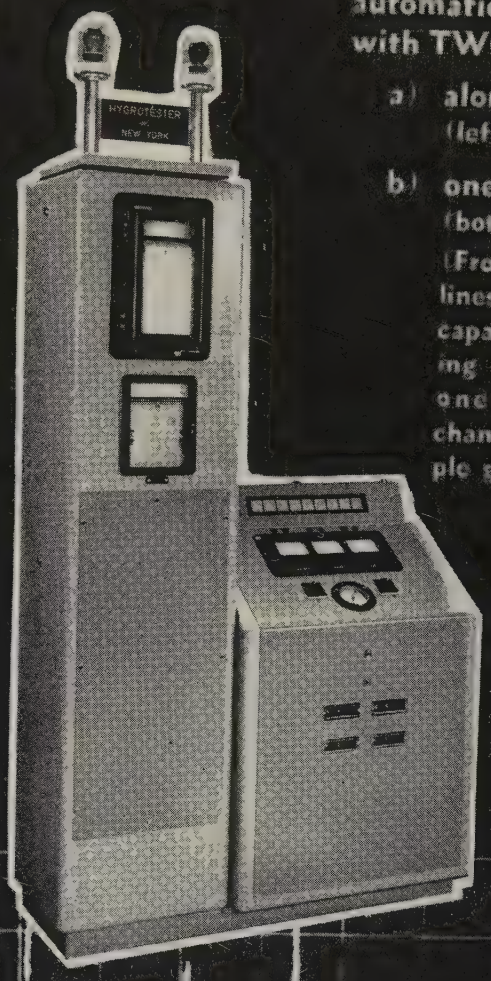
HYGROTESTER INC.
BROOKLYN 1, N. Y.

Supertest 712

most advanced, fully automatic moisture control, with traversing, automatically lifting capacitor, with TWO recording instruments

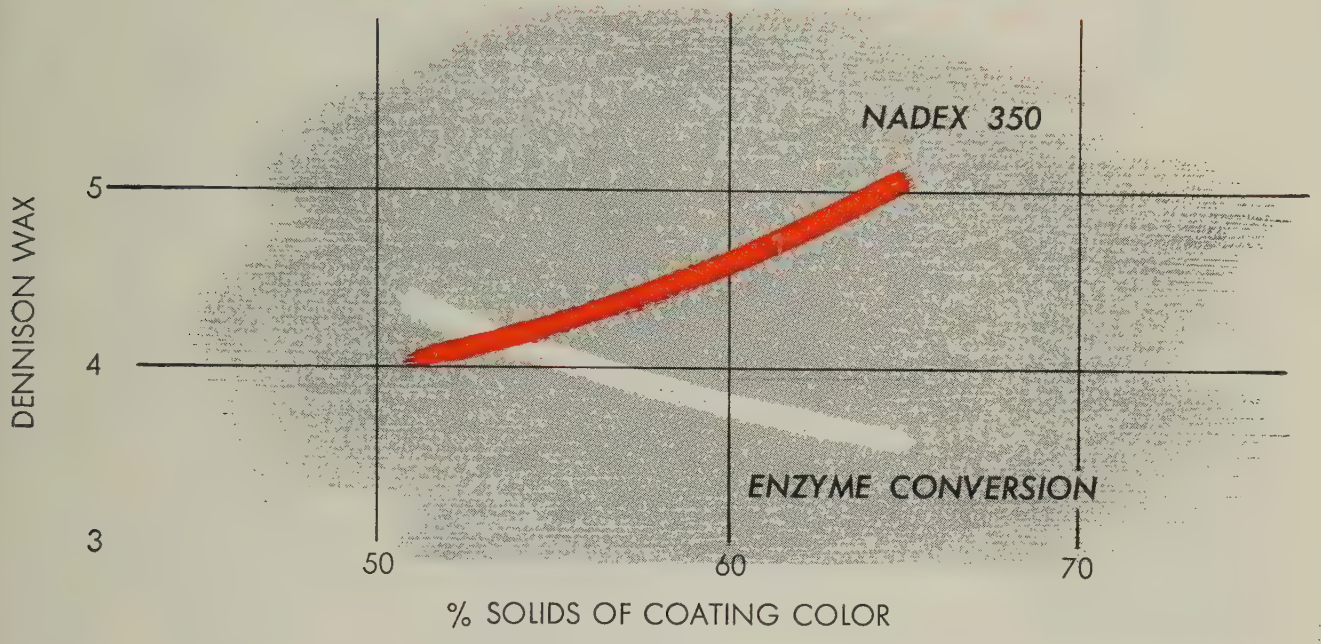
a) along the sheet
(left graph)

b) one-way-across the sheet
(bottom graph)
(Front side to back side, straight lines non-recording return of capacitor to front side. Recording length on chart-paper for one full-width traversing changeable up to 6¼" by simple gear shift).



HIGHER PICK

AT 65% SOLIDS



. . . for all coated stocks

NADEX 350 —a special dextrin for coating. Gives a higher pick than enzyme converted starches when used in high solids coatings. No matter what the stock.

NADEX 350 need only be cooked. No need for expensive conversion equipment, enzymes, extra technician time.

NADEX 350 can be cooked at 47% solids. There's more water available for pigment dispersions. Fewer formulating problems.

NADEX 350 offers good strength, adequate stability, high uniformity, and lower viscosity characteristics for machine or off machine coating.

For full information on NADEX 350 or on National's other coating dextrins or starch products write —

National
STARCH PRODUCTS

270 Madison Avenue, New York 16, N. Y.

Experience and service make the difference when you buy Ansul Sulfur Dioxide

The chemist in the background (above) dates us—August of 1915 to be exact. This was the month and year we shipped our first cylinder of liquid sulfur dioxide.

A good deal of our energies during the past 40 years have been devoted to perfecting a quality-control system for the manufacture of sulfur dioxide. Today, it's no trick at all to supply our customers with a near 100 percent pure grade (99.9%) of this chemical.

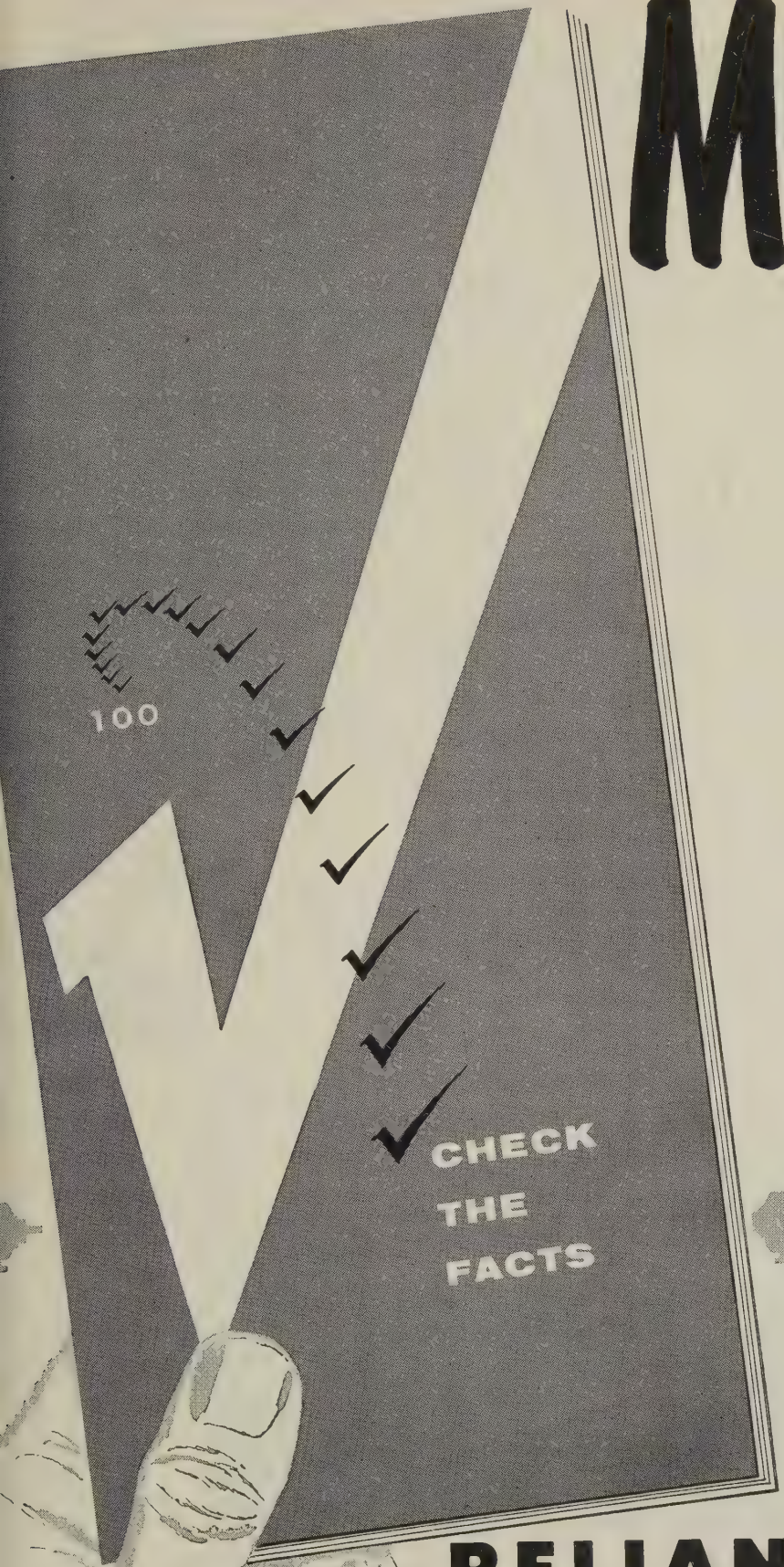
Equally important, to our way of thinking (our customers' too), has been the growth of our service facilities. Over the years we have been privileged to serve and instruct a host of paper manufacturers in the economical application of sulfur dioxide. This background of diversified experience is available for your use.

We would like the opportunity to show you the many advantages gained by installing an Ansul liquid sulfur dioxide system. The years have proved that it is the sure, economical way to cut cooking time and keep sulfite pulp production going at an even rate *in spite of* wet or green wood cooks or high water temperature. Ansul sulfur dioxide is also used in chlorine bleaching, in peroxide bleaching and in semi-chemical pulping. Write us for more information. ANSUL CHEMICAL COMPANY, Dept. C-46, Industrial Chemicals Division, Marinette, Wisconsin.

ANSUL

EW

TOTALLY PROTECTED A-C. MOTORS



Yes, it's true!

Industry everywhere is checking into the facts about these amazing new *Totally* Protected A-c. Motors by Reliance.

To help *you* check the facts to see where it fits into *your* production area, we've prepared a booklet called "Check the Facts".

Get your copy today—by mail, or through your local Reliance district sales office or distributor.

B-1489

RELIANCE ELECTRIC AND ENGINEERING CO.

Canadian Division: Welland, Ontario

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RELIANCE MOTORS

Builders of the Tools of Automation

RELIANCE V-S DRIVE

How Celite increases opacity up to 50%

. . . and improves printing surface, too!

LEADING paper mills have increased opacity of sheet up to 50% by adding small quantities of Celite* diatomite powders to their furnish. At the same time they have obtained better absorption qualities such as improved ink receptivity.

A test run in your mill will quickly demonstrate how you may secure similar advantages. You will find that Celite has a highly porous structure and excellent suspension properties, resulting in high retention of the Celite and also of the hiding pigments. Celite increases sheet opacity more than any other common mineral filler.

Saves $3 to $15 per ton of pulp

Celite is even more effective, however, when used in combination with TiO_2. It helps retain more TiO_2 in finished sheet, gives dry opacity and high brightness equal to that when TiO_2 is used alone. And since a substantial portion of costly TiO_2 is replaced with lower-cost Celite, savings of $3 to $15 result for every ton of pulp.

To prove these advantages of Celite, a Johns-Manville Celite Engineer will gladly assist you in making trial runs in your mill. There is no charge for his services. Simply write Johns-Manville, Box 60, New York 16, N. Y.

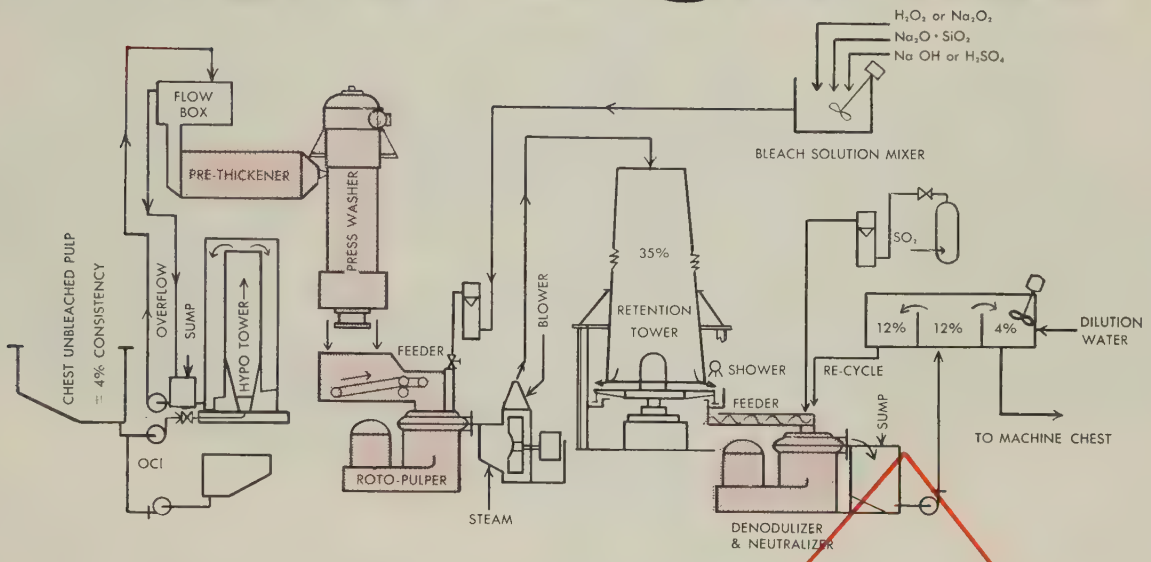
*Celite is Johns-Manville's registered trade mark for its diatomaceous silica products.

JOHNS-MANVILLE JM PRODUCTS **Johns-Manville CELITE** PRODUCTS FOR THE PAPER INDUSTRY

now you can have both...

lower cost

higher brightness



in the new J-C groundwood bleaching system!

For four years J-C's single stage groundwood bleaching system has provided high brightness at reduced costs for various mills.

Now a new and better process . . . the dual-stage system . . . has been perfected by J-C engineers to give outstanding savings in chemical consumption and greater increases in brightness.

Look over this list of reasons and see for yourself how this new process produces a better product at a far lower cost.

fully continuous, precision controlled system
low initial investment
much lower operating costs per ton
minimum floor space
sharply reduced yield loss
maximum brightness
minimum color reversion
unchanged pulp physicals
one operator per shift
freedom from knots and "fish eyes"

Your nearest J-C representative will tell you how it is done!

The Tayler Corp.
46 Trinity Place
New York 6, N. Y.
Phone BO 9-6496
Export only

Homad Services Ltd.
1445 Crescent St.
Montreal 25, P.Q.
Phone Belair 5419

John D. Homan
714 S. Orleans Ave.
Tampa 6, Fla.
Phone Tampa 8-3952

M. O. Grove & Co.
310 Sacramento St.
San Francisco 11, Calif.
Phone Yukon 6-1611

Jas. Brinkley & Co.
417 Ninth Ave. So.
Seattle 4, Wash.
Phone Maine 0062

Frank C. Bacon
3176 W. 32nd Ave
Vancouver 8, B.C.
Phone KE-7098

J-C

JACKSON & CHURCH CO. SAGINAW, MICHIGAN

Work well done since eighty-one

Whatever your white water problem — reclamation or disposal — Dicalite filtration provides the answer. And it's an economical answer, too. For in taking out the "white," Dicalite filteraids trap all the solids which give white water its name . . . furnish components such as fibers, fillers, pigments, etc., all of which (including the filteraid itself) can be re-used to lower your furnish costs.

And what of the filtered water? It comes from the filter brilliantly clear, equal to fresh water (and often better) for re-cycling in most closed or partially closed systems. Add a small amount daily of fresh make-up water, and you have no disposal problem at all. Or, if disposal is your plan, you can discharge this clear, clean water to waste, secure in the knowledge that it meets or surpasses every requirement ever established to protect our waterways against pollution.

White water filtration is one important use of Dicalite in papermaking. The other is as a paper-aid (or filler), which may be even more important to you than the white water problem. Let us send you complete information . . . just write to

Dicalite Division · Great Lakes Carbon Corporation
612 South Flower Street, Los Angeles 17, California

Dependable GLC GREAT LAKES Dicalite® DIATOMACEOUS MATERIALS

Asten DRYER FELTS

VALLEYFIELD
QUEBEC

Expansion

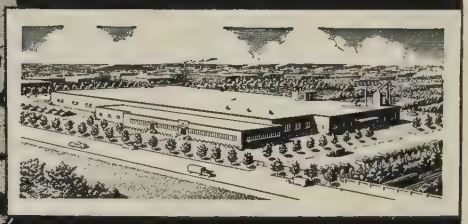
of service to the paper industry

To meet the needs of our customers, the manufacture of ASTEN Dryer Felts in the United States will soon be augmented by a second plant located at Walterboro, South Carolina.

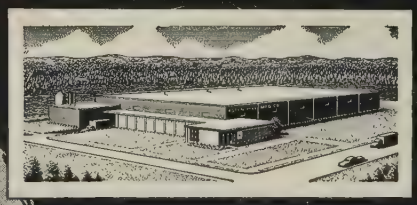
Besides speedier delivery to mills in the South, these new facilities will provide added assurance of emergency supply to ASTEN users everywhere. This modern plant will be in early operation.

Economy in the long run

PHILADELPHIA
PENNA.



WALTERBORO
SOUTH CAROLINA



ASTEN-HILL MFG. CO. PHILADELPHIA, PENNA.
WALTERBORO, S. C.

ASTEN-HILL LIMITED VALLEYFIELD, QUEBEC

PAPER

KEEPS COMING...

...AND COMES

CLEAN

WITH W&T CHLORINATION

No slime formers . . . no contaminating organisms . . . no objectionable tastes, odors or colors . . . paper keeps coming without a slime break, and comes *clean* when a Wallace & Tiernan Chlorination system safeguards the fresh and white waters.

Whether your mill produces pulp, newsprint, kraft, writing, tissue, or board, the quality of your product and the efficiency of your mill depend on clean, biologically pure water. For information on how to get biologically pure water most economically, write our Industrial Division.

WALLACE & TIERNAN
INCORPORATED
25 MAIN STREET, BELLEVILLE 9, N. J.

1-50

Tonnage Goes Up . . . Costs Go Down

WITH **claflin** CONTINUOUS BEATERS AND REFINERS

Claflin refiners and beaters have proven time after time that they produce more pulp . . . of higher quality . . . for less cost.

Pulping costs are less because there is less loss through rejects and re-refining.

Power Costs are cut from the 3-4 hp. days/ton average to 2.0 hp. days/ton. In some cases Claflins are doing the job for even less.

Quality and paper strength increased. Pulp that is "Claflinized" forms well on the paper machine. No lumps . . . no clots . . . no clumps.

No foaming problems. Claflins operate on a closed system. Air is not introduced into the refining cycle at *any* point.

Write for full Information Today!

claflin CONTINUOUS BEATERS AND REFINERS

THE HERMANN MANUFACTURING COMPANY — LANCASTER, OHIO

A COMPLETE STARCH SERVICE FOR THE PAPER & PAPER CONVERTING INDUSTRIES

IDAHO POTATO STARCH

MAINE POTATO STARCH

DANISH POTATO STARCH

DUTCH POTATO STARCH

PRE-GELATINIZED POTATO STARCH

TAPIOCA FLOUR

CORN STARCH

AMERICAN KEY PRODUCTS, INC.

12 EAST 42 STREET NEW YORK 17, N. Y.

Sales Representatives:

San Francisco: Bloch & Co.
Chicago : Roy A. Asmussen & Associates Inc.
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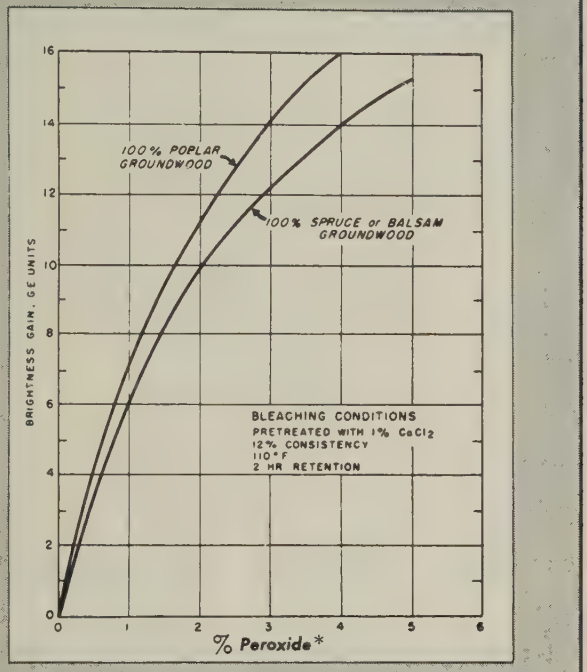
NOW... Increase groundwood brightness 10-14 G. E. units

with the Du Pont Peroxide Bleaching Process



BRIGHTNESS GAIN WITH VARYING PEROXIDE CONCENTRATION AT OPTIMUM TOTAL ALKALINITY

*As "Solozone," "Albone" or Combination of Both.

No other process gives you such high, stable brightness levels!

Now you can bleach groundwood for use in high-brightness papers with the Du Pont Peroxide Process. Higher concentrations of peroxides make high, heat-stable brightness levels possible—*increases of 10-14 G.E. units where needed!* And adjustments in bleaching formulas to improve brightness involve no changes in existing equipment.

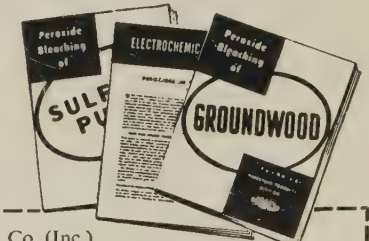
While increasing pulp brightness, this economical Du Pont process preserves the desirable characteristics of groundwood: high opacity, good formation and excellent printing properties.

You'll save with exceptionally high fiber yields. And peroxide bleaching minimizes brightness reversion on the paper machine.

Send for our new bulletin P62-1054 on High-Brightness Bleaching of Groundwood. It tells you how you can increase your groundwood brightness for more profitable papers. Mail coupon for your copy.

Send for these Du Pont booklets on peroxide bleaching of groundwood and sulfate pulps. They contain detailed information on formulations, procedures and equipment for the process, along with chemical control tests for bleaching solutions. Mail coupon for your copies.

Du Pont Peroxides are available for prompt delivery from conveniently located manufacturing plants. You can be assured of a dependable supply of top-quality peroxides for all your bleaching needs.



DU PONT
PEROXIDES

Albone®.....Hydrogen Peroxide
Solozone®.....Sodium Peroxide

DU PONT
REG. U.S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY

E. I. du Pont de Nemours & Co. (Inc.)
Electrochemicals Dept. T-2, Wilmington 98, Delaware

Please send me literature checked below:

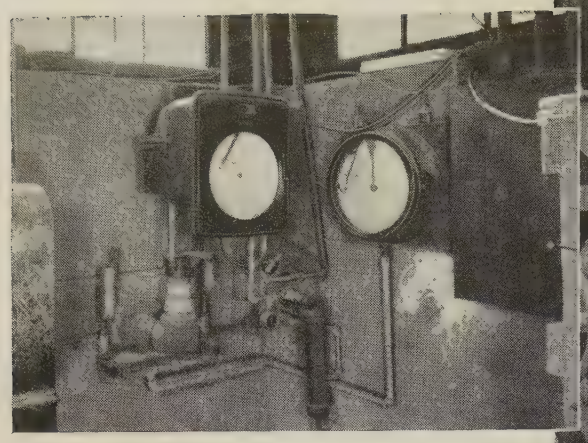
- ☐ Bulletin P62-1054, "High-Brightness Bleaching of Groundwood"
- ☐ Booklet, "Peroxide Bleaching of Groundwood"
- ☐ Booklet, "Peroxide Bleaching of Sulfate Pulp"

*Name*_____

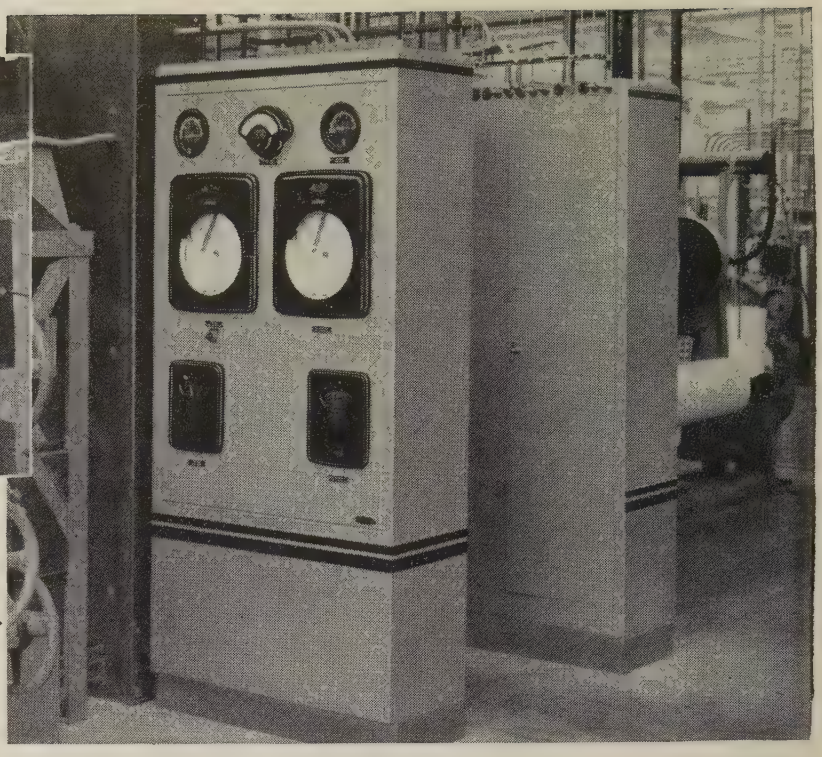
*Firm*_____ *Position*_____

*Address*_____

*City*_____ *State*_____



This is part of an old-fashioned installation which lacks the convenience and efficiency of modern instrumentation.

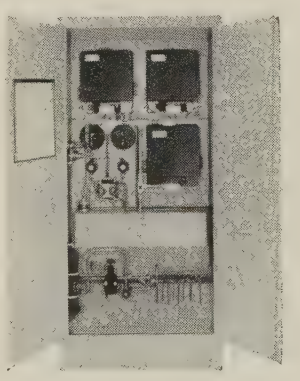


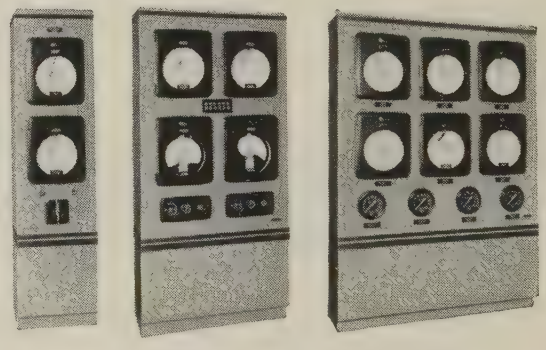
Compare this centralized Foxboro Cabinet installation of similar instrumentation, which saves time for the operator, makes his work more efficient, and gives maximum protection to the precision instruments required for his process.

See what a difference FOXBORO cabinet-mounting can make!

These photos show at a glance how much more efficient and attractive your instrument installation can be if it's integrated and centralized in a Foxboro Cabinet. Not only are the instruments protected from dust and process "atmospheres", but they're conveniently grouped together for more efficient use and easier maintenance. Those "endless steps" of the operator are a thing of the past!

Foxboro will supply a cabinet (or cabinets) to house and protect any number of existing instruments and related devices. Or your order for new instruments can be shipped to you already mounted in cabinets, completely piped and wired, needing only simple power and process connections to be put into operation. Write for illustrated and informative Bulletin 413.





Foxboro Cabinets are available in three standard sizes for 2, 4, or 6 conventional-size instruments (or equivalent). For mounting more than 6 instruments, Foxboro Sectional Cabinets (with open ends) are used . . . bolted together to form desired length. End sections have one closed side to form dust-tight enclosure. Exclusive insert-type panel construction permits easy conversion when process changes so require.

THE FOXBORO COMPANY, 782 NEPONSET AVENUE, FOXBORO, MASS., U. S. A.

FOXBORO
REG U S PAT OFF

PROCESS CONTROL CABINETS

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

"...without cost or obligation"

Another pulp bleaching problem solved. He's heading back to Syracuse . . . home and family . . . and maybe a stretch of regular hours in the lab.

Maybe, that is.

A SOLVAY Technical Service man's job can take him any place where there's a customer in need of assistance in handling or using SOLVAY products.

If he's in the Pulp and Paper Section, he may jump from a chlorine dioxide installation in Georgia to a pulp mill in Maine or Michigan that's having trouble. Yes, days and even nights "in the field" probing problems with the customer's technicians . . . and applying answers that the Pulp and Paper Section's years of specialized experience and endless research have uncovered.

Seems like quite a job ". . . without cost or obligation". But, SOLVAY has always felt that its responsibility as a manufacturer extends into the plants of its customers—to assure them of peak efficiency from the chemicals that set the standard for the industry.

SOLVAY can supply these not-ordinarily-available services because its Technical Service has separate sections for different industries.

SODA ASH

CAUSTIC SODA

LIQUID CHLORINE

CALCIUM CHLORIDE

SOLVAY

SOLVAY PROCESS DIVISION

ALLIED CHEMICAL & DYE CORPORATION

61 Broadway, New York 6, N. Y.

Allied Chemical

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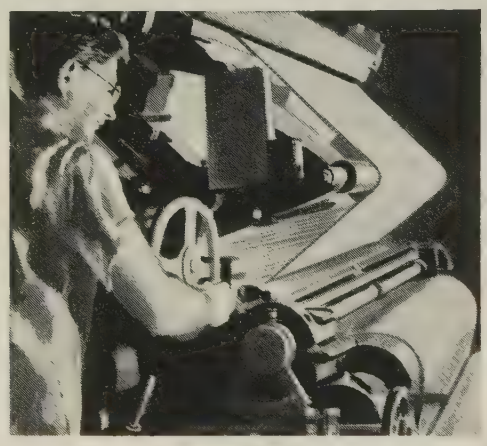
Soda Ash • Snowflake® Crystals • Potassium Carbonate • Calcium Chloride • Sodium Bicarbonate
Ammonium Bicarbonate • Cleaning Compounds • Caustic Potash • Sodium Nitrite • Caustic Soda
Ammonium Chloride • Chlorine • Monochlorobenzene • Para-dichlorobenzene • Ortho-dichlorobenzene
Chloroform • Methylene Chloride • Methyl Chloride • Carbon Tetrachloride

BEATER ADDITIVES

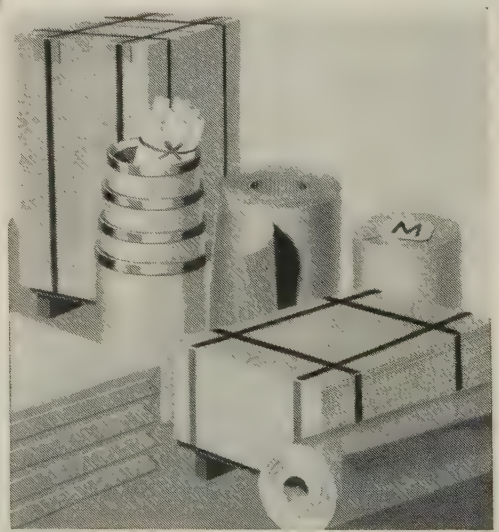
Hercules Brand Corn Starches are always considered when high grade paper must be produced. Hercules Starches enable the manufacturer to obtain an almost colorless, transparent, thin film which insures greater surface coverage with less rosin.

HERCULES® STARCHES FOR QUALITY PAPER



HIGHER MULLEN

These exceptional starches close the pores of paper, lay the fuzz on the surface and increase the tensile strength, fold test, as well as bursting strength. Hercules Corn Starches lend a pleasant feel and rattle to paper.



SURFACE SIZING

The characteristics of Hercules Starches assure perfect functioning as a surface sizing... improving the printing surface, obtaining a better "pick" test and preventing printing ink from feathering.

Our field and laboratory experts welcome an opportunity to help you with your current problems. Write today.

CORN PRODUCTS REFINING COMPANY • 17 Battery Place, New York 4, N. Y.

for maximum process stability and economy

now nondusting

Solar Colors

Unsurpassed for the tinting of white papers because they are least affected by fluctuations in pH or temperature. Solar Colors offer—

- **Maximum brightness of shade**
- **Excellent light fastness**
- **Quick wetting-out**
- **Uniform dispersion**

Solar Colors are now being delivered in a new nondusting, noncaking form which completely eliminates handling difficulties.

Solar Blues and Violets are available in a full range of shades which will produce tints of any possible hue for the brightest whites or coated papers with unexcelled color *performance*.

All these advantages are available at no extra cost.

Write for samples and technical information on the role of Solar Colors for tinting white papers.

From Research to Reality

GENERAL DYESTUFF COMPANY

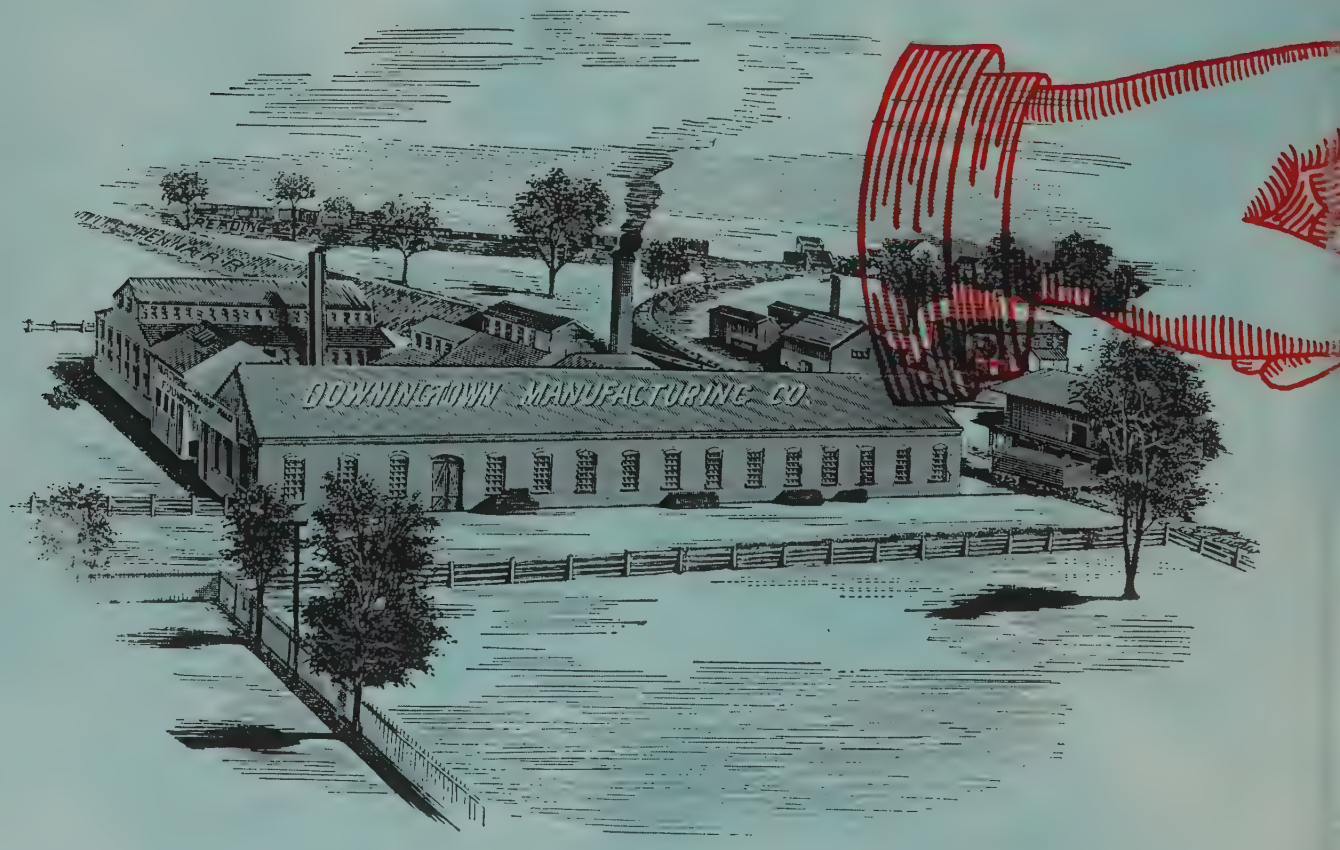
A SALES DIVISION OF GENERAL ANILINE & FILM CORPORATION

435 HUDSON STREET • NEW YORK 14, NEW YORK

BOSTON • CHARLOTTE • CHATTANOOGA • CHICAGO • LOS ANGELES • NEW YORK • PHILADELPHIA • PORTLAND, ORE. • PROVIDENCE • SAN FRANCISCO

DOWNINGTOWN

Celebrates their **75** *Years of Progress*



in

PAPER MACHINERY MANUFACTURE

1880-1955

It is generally agreed that in the last 75 years greater progress has been made in the manufacture of paper and board products than was accomplished in the preceding 2000 years. Downingtown, this year celebrating its 75th Anniversary, has been continually in the forefront of this progress, contributing many "firsts" to improve quality, speed production and lower costs in the great American paper industry.

Downingtown is dedicated to continue these contributions this year and in many years to come.

Downingtown Manufacturing Co.
Downingtown, Pa.

DOWNINGTOWN

DESIGNERS AND BUILDERS OF PAPER, BOARD AND FELT MACHINES

75 *th year*

West Coast Subsidiary:
MONARCH FORGE & MACHINE WORKS, Portland 10, Oregon

lives: UNITED STATES MACHINERY CO., INC., 90 Broad St., New York 4, N.Y., JOHN V. ROSLUND, Pacific Building, Portland 4, Oregon, THE EMERSON MFG CO., Lawrence, Mass., KOEHRING-WATEROUS, LTD., Brantford, Ont., Canada

IN CANADA

A COMPLETE RANGE OF HIGH QUALITY PRODUCTS FROM CORN FOR THE PAPER INDUSTRY

Sizing starches for beater, tub, and calender

Including the new starch ethers

Corrugating starches

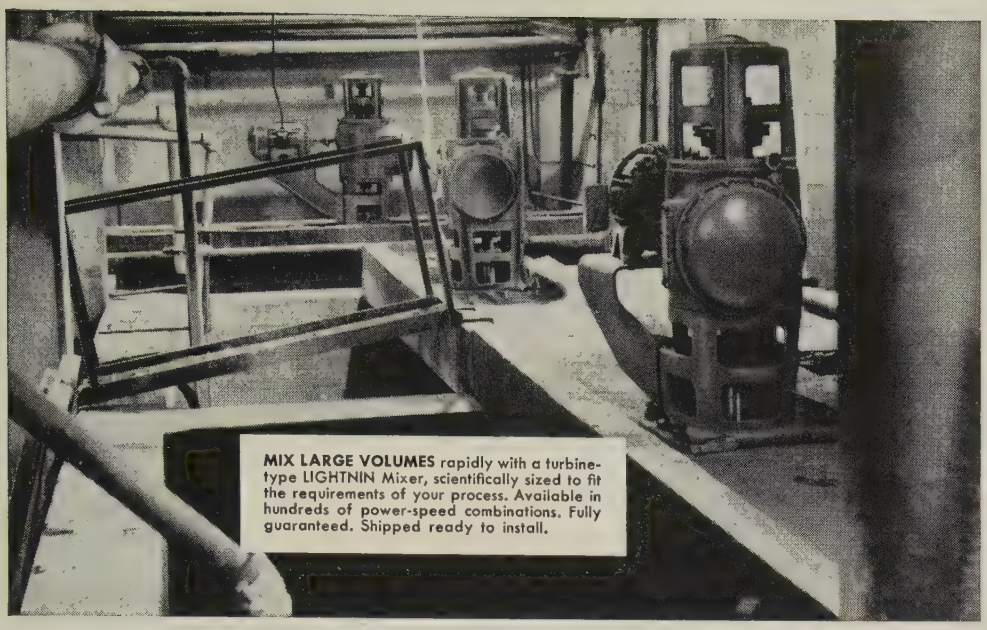
Starches for paper coating

Glucose as an ideal plasticizer

Contact for your requirements and technical information

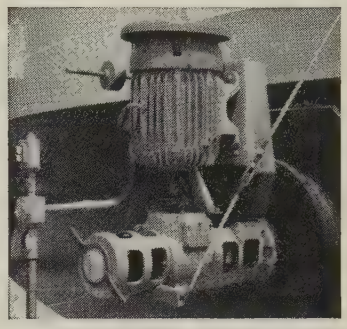
ST. LAWRENCE STARCH COMPANY LIMITED

PORT CREDIT ESTABLISHED 1889 **ONTARIO**



MIX LARGE VOLUMES rapidly with a turbine-type LIGHTNIN Mixer, scientifically sized to fit the requirements of your process. Available in hundreds of power-speed combinations. Fully guaranteed. Shipped ready to install.

UNIFORM 6% STOCK, without costly control measures, is produced in vertical unbaffled stock chest by heavy-duty LIGHTNIN. Sizes to 500 HP.



CUT MAINTENANCE to a new low with LIGHTNIN Side Entering Mixers in rectangular chests and smelt dissolving tanks. Shut off mixer stuffing box from tank, for repacking, as simply as turning a valve. Or specify the new, fully-tested, quickly replaceable mechanical shaft seal that eliminates *all* repacking—forever!

Do your fluid mixers give you maintenance savings like these?

There are no costly maintenance headaches hiding in the tanks you see above.

Even though the shaft on the turbine-type LIGHTNIN Mixer is 12 feet long, it runs smoothly—and safely—without the nuisance and expense of a submerged steady bearing on the tank bottom.

What's more, the gears in this mixer will never need replacement because of damage caused by flexing of the overhung shaft.

Even if someone accidentally drops a heavy sack of material on the impeller while it is turning, the shock can't reach the gears. They're protected by a unique hollow-quill construction that insulates shaft from gearing.

How interchangeable parts protect you

There are no "special" parts in the mixer. It is built entirely of standard, mass-produced components, easy to replace on short notice.

If your process should ever change, you can in all probability convert your LIGHTNIN Mixer to fit the new conditions, without drastic reconstruction. Mountings, shafts, impellers are all interchangeable.

You can change even the *speed* on a turbine-type LIGHTNIN—by replacing two easy-to-get-at gears, without dismantling the unit or taking it off the tank.

What this means to you

These advantages add up to a low rate of mixer obsolescence—as well as low maintenance cost—when you mix with LIGHTNIN Mixers.

Thousands of LIGHTNINs are in service now. Hundreds have been in service 20 years and more.

For quick, competent help on any fluid mixing operation in your mill, call your LIGHTNIN Mixer representative. Or write us today.

Lightnin® Mixers

GET THESE HELPFUL FACTS ON MIXING

LIGHTNIN Catalogs contain practical data on impeller selection; sizing; best type of vessel; installation and operating hints; full description of LIGHTNIN Mixers. Yours without obligation. Check and mail coupon today.

MIXCO
fluid mixing specialists

- ☐ DH-50 Laboratory Mixers
- ☐ DH-51 Explosionproof Laboratory Mixers
- ☐ B-102 Top Entering Mixers (turbine and paddle types)
- ☐ B-103 Top Entering Mixers (propeller type)
- ☐ B-104 Side Entering Mixers
- ☐ B-106 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet
- ☐ B-108 Portable Mixers (electric and air driven)

MIXING EQUIPMENT Co., Inc.
142-b Mt. Read Blvd., Rochester 11, N. Y.

In Canada: Greey Mixing Equipment, Ltd.
100 Miranda Avenue, Toronto 10, Ont.

Please send me, without obligation, catalogs checked at left.

Name_____ Title_____

Company_____

Address_____

City_____ Zone_____ State_____

CONTEST

for Capable Engineers only

Guess the name of this manufacturer of vacuum equipment

PRIZES:

1. **GRAND PRIZE** — Trip around the universe.
2. **SECOND PRIZE** — Option on the Brooklyn Bridge.
3. **THIRD PRIZE** — Six pairs of three-legged overalls.
4. **ONE THOUSAND RUNNER-UP PRIZES** — one thousand ouija boards.

CLUES:

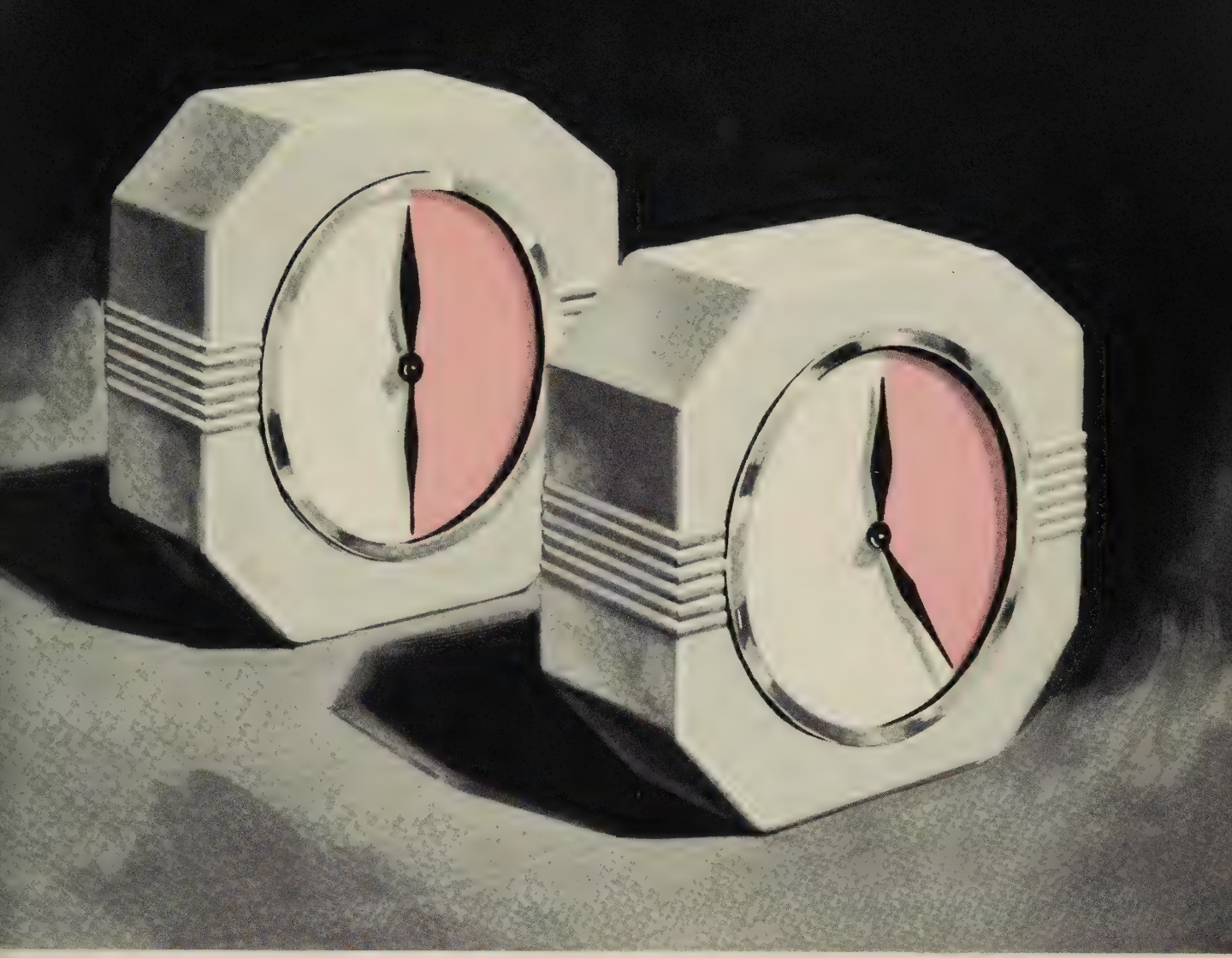
1. Company founded in 1917.
2. Both original founders still active in the business.
3. Each founder has a son thoroughly trained in engineering who is also active in the business.
4. The company has specialized in jet vacuum equipment more than any one firm.
5. Has made hundreds of jet cooling units in capacities up to 3000 tons of refrigeration.
6. Makes an extensive line of other jet equipment including jet mixers, jet heaters, jet absorbers, jet pumps, and jet fume scrubbers.
7. Has designed and built thousands of barometric condensers in standard and a great variety of special materials.

Why, of course it's

CROLL-REYNOLDS CO., INC.

Main Office — 751 Central Ave., Westfield, New Jersey Phone Westfield 2-4200
New York Office — 17 John Street, New York 38, N. Y. Phone Cortlandt 7-5531

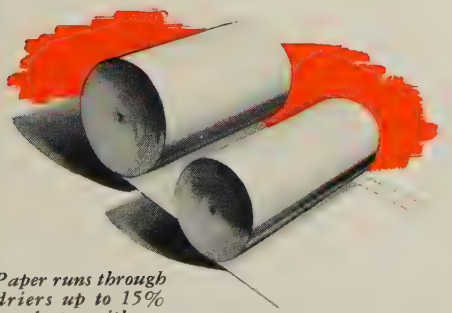
CHILLVACTOR UNITS • EVACTOR STEAM JETS • CONDENSING EQUIPMENT



Drying time reduced up to 15% with Alpha Protein®

...THE HIGH SOLIDS COATING ADHESIVE FOR OFFSET PAPERS

Solids in coatings increased up to 12% by ALPHA PROTEIN



Paper runs through driers up to 15% faster with ALPHA PROTEIN

Now you can cut the costly expense of drying machine coated offset papers by as much as 15%. Glidden is doing it today for many leading paper coaters with Alpha Protein. You don't have to tie up costly equipment to find out what this superior adhesive can do for you. Glidden Technical Service men have the equipment to pilot test it in their own laboratories under similar conditions found in your plant. Call Glidden for fast, competent service on all of your high solid coating needs.

This advertisement is printed on paper processed with Glidden Alpha Protein. It is typical of the superior reproduction that can be obtained.

THE GLIDDEN COMPANY

Chemurgy Division

1825 N. Laramie Street • Chicago 39, Illinois

QUALITY Glidden PRODUCTS

SCIENTIFIC CONSTRUCTION*

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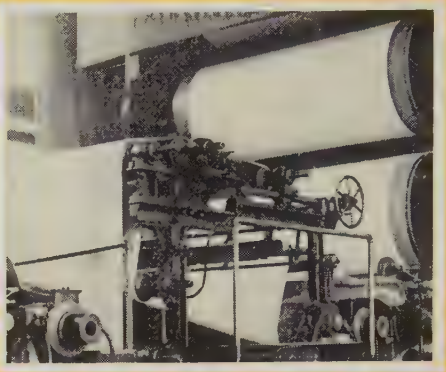

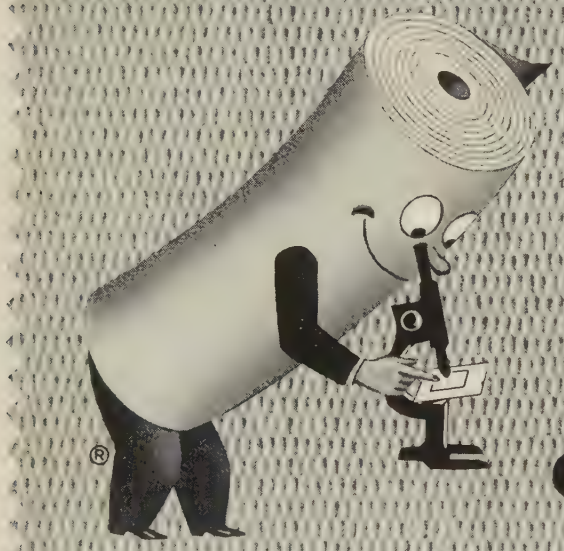

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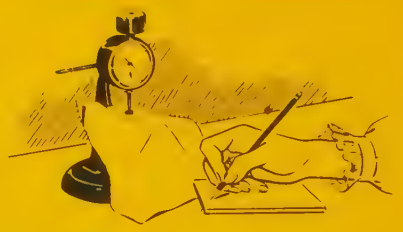


One of a series of comprehensive laboratory controls throughout production to assure uniformity in all Mt. Vernon-Woodberry products. Here fabric thickness after weaving is being gauged.

The Coordinate Role of Alum in the Sizing of Paper

R. M. KARAPETOFF COBB and DONALD V. LOWE

The role of alum in paper sizing was investigated from the viewpoint of coordination of both cellulose fiber and insoluble rosin sizing precipitate by aluminum ion. After introductory consideration of the coordination theory the experimental work consisted of three parts: (1) establishing the minimum sizing film, (2) determining optimum conditions for rosin size precipitation, and (3) establishing the coordinate role of alum in sizing, through the precipitation of rosin size by aluminum salts whose cations varied in coordinating tendency. This work led to the discovery of the alum concentrations necessary for proper coordination, as manifest by high contact angle and good sizing; and also led to an explanation of the sizing problems encountered in hot weather, when sizing may be blocked or destroyed by the production of anions which are too highly coordinated to aluminum.

THE work to be described in this paper was started in 1938 at the suggestion of D. V. Lowe, who felt it was about time to learn just why alum was used in the sizing of paper, and whether so much alum should be going down the sewer every year.

The theory of Arthur W. Thomas (*40*) of Columbia University, that aluminum might be effective in paper sizing, because aluminum was one of the elements whose cation could coordinately bind both cellulose and anionic sizing material, had been of great interest to us ever since Thomas promulgated it at the TAPPI sizing symposium in 1935. The work to be undertaken afforded a welcome opportunity to prove or disprove the idea of the coordinate role of alum in sizing.

Results obtained in the investigation were, in a sense, so startling at that time, that it was felt they should not be published until they had been thoroughly checked, awaiting an opportunity which the war years just did not afford. A brief two-sentence summary of the findings for the coordinate role of alum in sizing was, however, included by Cobb (*9*) in the third edition of Sutermeister, published in 1941, where it has evidently passed unnoticed, or at least unquoted.

But the publications since 1942 of Wilson (*43, 44*) on aluminum bonds; of Price (*31, 32*) and of Price and Cameron (*33*) on acid, alum, and the alum-rosin precipitate; of Duston (*16*) and of Porter and Lane (*30*) on the use of aluminum chloride have verified our findings so that such checking and rechecking seemed less essential.

And most notable of all, there came the publications by Collins, Davis, and Rowland (*11*) and by Thode, Gorham, and Atwood (*39, 19*) with their electrophoretic mobility determinations of rosin-aluminum sulphate complexes, which in some respects have gone far beyond the work to be described here. This brought the realization that if ever these data on the coordination theory were to be presented, the time for it was now, when it could be of value in confirming the results of others from a somewhat different point of view.

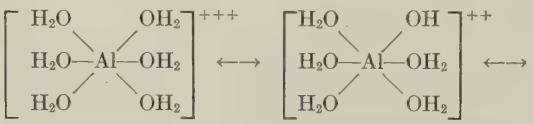
R. M. K. COBB, formerly Research Director, at present Technical Adviser, and D. V. LOWE, President, Lowe Paper Co., Ridgefield, N. J.

THE COORDINATION THEORY OF A. W. THOMAS

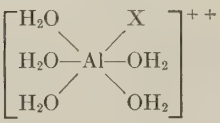
The number of water molecules attached to a cation is called the coordination number and is determined by the size of the cation. Small cations such as Be^{++} coordinate four water molecules, forming $Be(OH_2)_4^{++}$. Aluminum, being larger, coordinates six water molecules, forming the hexahydrate $Al(OH_2)_6^{+++}$. The forces between terpositive ions and the water molecules are so strong that the cations often retain a layer of water molecules in their crystals, as water of hydration. In the alums such as $Al_2(SO_4)_3 \cdot 18H_2O$, 12 of the 18 water molecules are attached to the aluminum ions. The rest are supposedly packed near the sulphate ions.

At a symposium on sizing held by TAPPI in 1935, A. W. Thomas (*40*) presented his well-known work on the structure and behavior of basic aluminum complexes, and related these to paper sizing.

According to Thomas, the hydrolysis of an aluminum salt in a Werner (*42*) *ol* complex goes as follows:



Hexa-aquo-alumini ion — Penta-aquo-hydroxo ion



Penta-aquo-X ion

The choice of the anion X, which will knock off a water molecule or an OH group and become coordinately bound to an aluminum ion in its place, depends upon the coordinating affinity of the anion X, compared to the coordinating affinity of the molecule or the anion already coordinately attached to the aluminum.

To illustrate this, Thomas quoted Charriou (*5*) who found that yellow chromate could not be washed out of a precipitate of aluminum chromate using water alone, or solutions containing nitrate, chloride, or acetate ions. On the other hand, Charriou found that bicarbonate, carbonate, phosphate, arsenate, sulphate, tartrate, citrate, or oxalate ions would leach out the chromate. Thomas also quoted Miller (*24*) who found that the presence of sulphate was necessary to attain flocculation of aluminum chloride by alkali at a pH of 5.3. If sulphate ions were not present, alkali could not flocculate aluminum chloride until the pH had been raised as high as 7.8. Further, Miller found that it was practically impossible to precipitate aluminum hydroxide that was free from sulphate or oxalate, if the aluminum solution originally contained these ions.

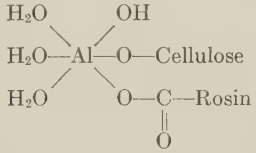
Accordingly, Thomas gave the order of ascending

coordinative affinity of the common anions for aluminum as:

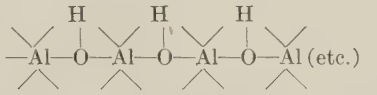
Nitrate (least coordinated)
Chloride
Sulphate
Acetate
Tartrate
Citrate = Oxalate
Hydroxyl (most)

which is an order of complex formation or coordination common to many metallic elements.

In the coordination theory, Thomas went on to state, a successful paper sizing arrangement would require a central coordinating atom, such as aluminum. The rosin or wax would be coordinately bound to the central aluminum ions, and so also, through its OH groups, would be the cellulose.



As Thomas (*40a*) points out, "This picture, while serviceable for the purpose of this paper, is far simpler than what actually occurs, because the basic aluminum ions in dilute solution tend to share their —OH (hydroxo) groups. And this builds up higher molecular weight complexes which may be depicted as



known as *ol* compounds (so named by Werner) and the process of polymerization called *olation* forming polyolated complexes.

"The coordination number of six for each aluminum is shown above by the valence lines. Attached thereto are H_2O molecules, and here and there anions (resinate, inorganic acids, and part of most anything else that may be in solution).

"Increasing binding of anions will, of course, lower the positive charge leading to ultimate precipitation of the polyolated aluminum complexes, or if sufficiently powerful coordinating anions are present, leading to reversal of charge of the olated aluminum complexes.

"Strongly coordinating anions play an additional role—they can reverse the process of olation, breaking down the complexes to lower molecular weight compounds (Stiasny *36a*).

"In regard to rate of olation, Perkins and Thomas (*28a*) showed that 20% basic 0.001 to 0.1 molar aluminum chloride solutions became 50% olated in a little over an hour."

The Other Roles of Alum

In attempting to demonstrate the importance of the coordinating power of alum, the other roles of alum in paper sizing should not be overlooked.

Alum obviously functions in precipitating the insoluble rosin sizing precipitate.

The effect of alum on the contact angle of the rosin-sized surface has to be considered.

According to Blodgett and Langmuir (*22*) when fatty acids are placed on water or on solutions of *monovalent* and *bivalent* salts a *fluid* film is formed. But when fatty acids are laid on solutions of *aluminum* salts the resulting films are *rigid solids*. While not part of this investigation, this unique rigid property of aluminum soaps is another important facet in the role which alum plays in the sizing of paper.

ESTABLISHING THE MINIMUM SIZING FILM

Choice of Paper Stock

In initiating the study of the role of alum in sizing, it was considered desirable to establish the minimum amount of rosin or wax that would raise the contact angle of cellulose fiber against water to such extent that the fiber could be declared sized-to-water. This minimum value was desired as a reference point. It was also hoped that the value thus found would be so low that it would serve as a challenge to learn some new coordinating twist for setting size, so that this small amount of sizing material could be made equally effective in the mill.

Referring to the sizing equation postulated in 1934 by Cobb and Lowe (*6*) from the Washburn (*41*) equation, and discussed later by Cobb (*7, 8*):

$$l^2 = \frac{r\sigma \cos \theta t}{2\mu}$$

where

l = depth of liquid penetration in centimeters
r = paper pore radius in centimeters
σ = surface tension of liquid in dynes per centimeters
$\cos \theta$ = cosine of angle θ taken by liquid in contact with solid
t = time of penetration in seconds
μ = coefficient of viscosity in poises; μ water —0.01006 poise at 20°C.

It was seen that the most telling conditions and the most dramatic demonstration of sizing through increase in contact angle would be obtained if the fibrous structure to be sized contained very large pores, so that all the burden of sizing would be carried by the contact angle.

To size a porous paper, for instance, with an initial absorbency of 6.00 grams water per 100 sq. cm. in 2 min. would call for a 400-fold reduction in cos θ to bring the absorption down to 0.30 gram per 100 sq. cm. in 2 min., where it could be considered well sized to water. The corresponding change in dynamic contact angle θ would be from 0° for the unsized stock to 89.8° for the sized stock.

Comparison of Paper Stocks for Size Impregnation

For preliminary evaluation of porous papers several highly absorptive unsized stocks were impregnated with aluminum resinate U.S.P. dissolved in benzene solution to give the desired strength of sizing material. Care was taken to prevent evaporation of solvent; the fibers were saturated in filled, sealed, jars overnight at room temperature.

The saturated samples were air-dried, and then tested with water using TAPPI Standard T 441 m-45.

Results, as shown in Table I, indicated that a heavy 0.030-in. blotting paper would be most difficult of all papers to size. Whatever quantity of sizing material was found to size such blotting paper satisfactorily, should be sufficient to size almost *anything*.

Accordingly, a 155-lb. 0.030-in. commercial white

Table I. Sizing Absorbent Papers with Aluminum Resinate

Al resinate on fiber, %	Cobb test: g. water/100 sq. cm./2 min. Blotting paper 155 lb. 0.030 in.	No. 5 filter paper	No. 4 filter paper	Unsized (filler) newsboard
0.0	6.00	5.02	3.44	4.49
0.02	6.00	4.28	3.20	..
0.06	6.00	4.05	3.06	..
0.18	5.70	4.01	3.10	..
0.35	4.54	3.15	1.93	0.24
0.60	1.17	0.47	0.52	0.21
1.75	0.24	..	..	0.19
3.50	0.24	..	..	0.19
6.20	0.20	..	..	0.12

Table II. Comparison of Sizing Agents on Blotting Paper

Material→	Sodium resinate	Gum rosin	Calcium resinate	Aluminum resinate	Paraffin wax
Solvent→	Benzene	Methyl alcohol	Benzene	Benzene	Benzene
Static contact angle[a]	..	60°	70°	100°	108°
Size on fiber, %	Cobb test: g. water/100 sq. cm./2 min.				
0.0	6.00	6.00	6.00	6.00	6.00
0.30	6.00	6.00	6.00	4.25	..
0.75	5.67	4.46	4.01	0.47	1.08
1.50	5.70	4.04	3.50	0.24	0.26
3.00	5.61	4.06	3.23	0.24	0.16
7.50	5.30	2.75	2.20	0.20	0.14
10.00	..	1.08	..	..	..

[a] Approximate average values testing with water on dry lumps of these sizing materials using TAPPI Standard T 458 m-45. The image of the drop of water was projected onto a paper surface, and tangents drawn at the point of contact of water and sizing material.

blotting paper with a solid fraction of 30.4% was used throughout the saturation experiments. The heavy blotter picked up: 1.25 times its weight of benzene solution, 2.50 times its weight of aqueous salt solutions.

Comparison of Sizing Materials

As the second phase of the study of the role of alum in beater sizing, aluminum resinate was compared with other sizing materials by similarly saturating blotting paper with the organosol. No alum was used.

Reference to the results in Table II indicated that aluminum resinate and paraffin wax, both of which had a naturally high contact angle against water, were satisfactory sizing agents. Calcium resinate, gum rosin, and sodium resinate (dry size), all of which had moderate contact angles against water, were not by themselves good sizing agents for porous stock. The difference between these findings and those of Minton (*26*), who advocated solvent sizing with gum rosin, may possibly be due to the difference in porosity of stock in the two cases.

The most important conclusion from this set of experiments on sizing by impregnation was that high contact angle against water seemed to be essential to effective sizing. Where sizing material did not have to be precipitated upon the fiber out of aqueous solution, coordination by aluminum ion was not necessary, as witnessed by the results with plain paraffin wax.

Setting the Size

When it thus became apparent that rosin alone, even from 8% nonaqueous solution, could not raise the contact angle of fiber sufficiently high to size an open, porous stock, the size was set with alum in the next set of experiments.

As before, blotting paper was saturated with nonaqueous solutions of gum rosin, and of sodium resinate in the form of dry size, and air dried. Other blotters were saturated with aqueous emulsion dispersions of paraffin wax and air dried.

A first attempt to set the dried sizing films by substituting alum solutions for the water in making the Cobb sizing tests, failed to develop the potential sizing values. Strong alum solutions—up to 10% $Al_2(SO_4)_3 \cdot 14H_2O$—were used to test the samples of blotter stock impregnated with hydrophobic sizing materials. But the size did not set and the absorption remained high for two possible reasons: (1) the 2-min. contact was too short, and (2) the size was not dried in the presence of alum.

Thereupon the dried size-impregnated blotter samples were given a second soaking, this time in aqueous alum solutions of varying concentration overnight, then redried in air at room temperature and tested with tap water.

Although this method of setting the size was open to obvious criticism because of the possibility of undetermined alum diffusion, it worked well and yielded the very interesting data of Table III.

Results in Table III. In contrast to the results in Table II, in Table III where alum was used to set the size, both gum rosin and sodium resinate were effective. As little as 0.5% of gum rosin or sodium resinate on the fiber raised the contact angle of heavy porous blotting

Table III. Setting Size on Blotting Paper with Alum Solutions of Various Strengths

Per cent on fiber: Gum rosin	Sodium resinate	Paraffin wax (emulsion)	Cobb test: g. water/100 sq. cm./2 min. Alum solution, % 0.05	0.1	0.5	1.0
0	..	..	6.00	6.00	6.00	6.00
0.30	..	..	2.24	..	..	..
0.50	..	..	1.76	0.32	2.08	2.48
0.75	..	..	1.44	..	..	..
1.00	..	..	1.48	0.24	0.64	0.80
2.00	..	..	1.40	0.24	0.32	0.32
..	0.5	..	..	0.24	1.00	3.00
..	1.0	..	...	0.16	0.42	2.00
..	2.0	..	...	0.16	0.40	0.40
..	5.0	..	...	0.16	0.20	0.20
..	..	0.5	...	..	2.56	2.40
..	..	2.0	...	..	0.56	0.40
..	..	5.0	...	..	0.40	0.32
..	..	10.0	...	..	0.40	0.32
Per cent alum on fiber (estimated from overnight absorption of 2.5 parts water to 1 part fiber)			0.125	0.25	1.25	2.5

paper to the point where it could be considered hard sized, after the alum soak.

Unfortunately, this Table III is as memorable for desirable data that were not obtained as for what it contains. For more complete data on paraffin wax, for example, reference must be made to Table II. But what data there are, were carefully checked. And there definitely seemed to be an optimum alum concentration above and below which, inferior sizing was obtained.

Importance of Alum Concentration at the Time of Sheet Formation

The sizing results obtained in Tables II and III answered the question as to the minimum amount of sizing material which, under favorable conditions, would size a stock as open and porous as blotting paper.

Rosin—0.5% on fiber
Paraffin wax—1.5% on fiber

But the results shown in Table III raised another question.

The traditional ratio of rosin to alum needed in sizing is 1 part rosin to 1.2 or 1.5 parts alum, although the theoretical ratio for the equally traditional reaction:

$$Al_2(SO_4)_3.14H_2O + 6C_{19}H_{29}COOH = 2(C_{19}H_{29}COO)_3Al + 3H_2SO_4 + 14H_2O$$

is only 0.30 alum to 1 rosin.

With consideration of the ratio of 1.5 alum to 1 rosin in mind, why then had it been possible to set 2.0% rosin size on the fiber at an alum concentration which would deposit only 0.25% alum on the fiber, when the traditional ratio of alum to rosin would call for 3% alum on the fiber? Could diffusion of alum from the solution into the fiber really account for this discrepancy?

This question about the necessary ratio of alum to rosin has been discussed many times in many places. Worry about the difference between the theoretical requirement for alum and the amount necessary in mill practice was a major feature of the Delaware Valley sizing symposium held in 1949 (*14*). Not much laboratory work had been done on the problem when McBain (*23*) in 1932, working with fatty acids, found that the *tribasic* salts of some fatty acids did not even exist, though the *monobasic* and *dibasic* salts were readily prepared. Cobb (*10*), in discussing the possible application of McBain's findings to the paper sizing field, pointed out that the ratio of alum to rosin required to form *disbasic aluminum monoresinate* $(C_{19}H_{29}COO)(OH)_2Al$ would correspond better to mill practice. Monoresinate would call for a ratio of 0.99 alum to 1.0 rosin; thus much closer to 1.5 than the ratio of alum to rosin called for by formation of the *tribasic aluminum resinate*, whose formation up to then seems to have been tacitly assumed by everyone.

Enthusiasm for this simple theoretical explanation of the mill alum/rosin ratio was considerably dampened when Price (*31*, *32*), in 1947 and 1948, found that analysis of rosin size precipitates formed in the laboratory indicated that they were composed of *monobasic aluminum diresinate* $(C_{19}H_{29}COO)_2(OH)Al$ + free rosin. *Monoresinate* was stated by Price to be absent.

Now, however, the very recent and interesting work of Ekwall and Bruun (*18*) has led these authors to the opinion that the best sizing film does consist of *dibasic aluminum monoresinate*, because the contact angle of that material is the highest one obtainable from rosin and aluminum. They believe the amount of alum should be controlled to give this monoresinate.

As it was, from previous work in the mill on alum, our suspicion had already been aroused that: the standard alum/rosin ratio of approximately 1.5/1 might be of far less importance to successful sizing and machine operation than was the absolute concentration of alum in contact with size and fiber at the time the sheet was formed. In other words, since machine conditions in paper mills were pretty much alike, the alum/rosin ratio of 1.5/1 might be a secondary coincidence. The real factor might turn out to be the absolute alum concentration which such a 1.5/1 ratio would ordinarily maintain in any mill.

The results outlined in Table III greatly increased that suspicion.

Consequently, the remainder of the work was centered around, and related to, the *absolute alum concentration as one of the most important variables in the sizing picture.*

DETERMINING OPTIMUM CONDITIONS FOR SIZE PRECIPITATION

Being firmly if somewhat intuitively convinced from the foregoing that if 0.5% rosin on fiber would size *blotting* paper, 0.75 to 1.0% rosin on *liner* stock would be a generous allowance, the next part of the investigation was concerned with the optimum conditions for precipitating that much rosin size on fibers in suspension.

Optimum Fiber Concentration

Selection of Consistency Range. Previous experimental work in the mill had indicated that rosin size precipitated at low stock consistencies was less adversely affected by high temperature, than was rosin size precipitated on the fiber at the beater consistencies of 6 to 8%. At vat consistencies it was at times possible to precipitate rosin on fiber at almost boiling temperatures and still get sizing.

Where there was one advantage, there might possibly be more. Therefore, it was decided to explore the low end of the fiber consistency scale to see how far down it was possible to go and still find the rosin floc absorbed by the fibers. It was felt that dilution would have a limit, and that the fields of force between rosin size and suspended fiber would not bridge too great a distance. This was the point to be investigated.

Thus a brief study was made of the minimum amount of beaten, virgin, unbleached sulphite fibers which had to be present in order to remove the alum-rosin sizing floc. Microscopic examination was employed to tell whether the floc had been adsorbed at each dilution, or whether, on the contrary, the floc had failed to attach to the fibers and was floating by itself in the watery dispersion.

Procedure and Results in Floccing Dilution. The rosin size was added to the sulphite stock at 8% consistency and the mixture diluted to the desired per cent fiber. Alum was added to pH 4.5 with hand agitation. After standing 10 min., a slide was made and the presence or absence of flocs between the fibers was noted, using 100 magnifications.

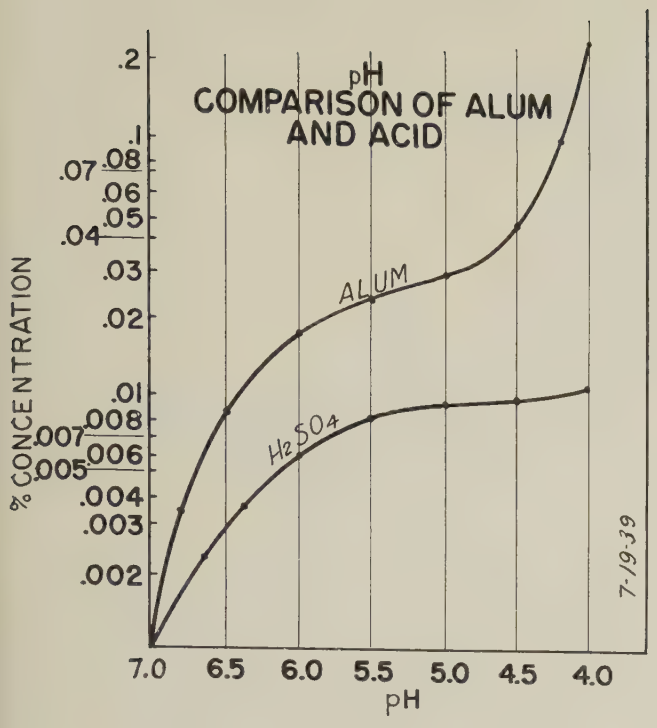


Fig. 1. Comparison of alum and acid

It was obvious from the results in Table IV that too great dilution of the size would, as was to be expected, result in incomplete precipitation of the sizing floc upon the fiber.

Table IV shows that the maximum dilution at which the floc was completely adsorbed, after precipitation by alum, was represented by a stock consistency of about 0.8%. Below that consistency, much of the precipitated floc was visible in the ordinary microscope, the floc floating loosely in the suspension. Since Thode, Gorham, and Atwood (*39*) noted that the number of rosin size particles visible in the microscopic field comprised not over 5% of the precipitate as normally formed, this microscopic criterion could hardly be presented here had it not been somewhat confirmed later by mill experience.

Table IV. Precipitation of Rosin-Alum Size at Different Sulphite Consistencies; 1.25% Dry Rosin Size on Fiber; Alum Added to pH 4.5

Fiber in suspension, %	*Consistency corresponding to*	*Equivalent rosin size concentration, %*	*Floc removal*
8	Beater	0.1	Complete
4	Headbox	0.05	Complete
2	Screens	0.025	Complete
0.8	Twice vat	0.01	Complete
0.6	1.5 vat	0.0075	Incomplete
0.4	Vat	0.005	Incomplete

Thus, on the cylinder machine, the optimum precipitation of rosin size might be expected to occur somewhere between the screen and the vat consistencies. This is no firm conclusion, for as mill experience has indicated, and the work of Thode, Gorham, and Atwood has explained, differences in agitation may be expected to affect the absorption of sizing complex. Nevertheless, the 1 to 2% stock consistency range would be an interesting one to explore in precipitating size in the mill, in an effort to find the consistency range where the sizing floc should prove to be neither too coarse nor too fine.

Adjusting pH for Sizing

Since pH had long been recognized as a factor equally as important as alum concentration in setting the size on the fibers, the comparative amounts of alum and acid covering the pH-sizing range were determined as shown in Fig. 1.

The laboratory work was done only on fresh well water without stock or size, though in our mill acid had been used for a long time right in the shavings stock together with alum, for economy and efficiency.

As stated subsequently in 1946 by Price and Cameron (*33*) three to ten times as much alum as acid was needed to obtain the pH values ordinarily maintained in sizing.

	Acid concentration, %	*Alum concentration, %*
For pH 5.0	0.009	0.030
4.5	0.010	0.050
4.3	0.010	0.100

Handsheet Procedure

Handsheets for TAPPI Sizing Test T 441 m-45. Although applicable to standard 2-gram samples, it is with handsheets of higher weights and thickness that the sizing test originated in our laboratory, and adopted as TAPPI Standard T 441 m-45, is most successful in sizing research. Accordingly, in all this work heavy handsheets were formed, averaging 7 grams for 49 sq. in., and 0.010 in. thick.

The regular 2-min. tests with water at 70°F. were found suitable for the zero-to-good sizing range. Unsized stock gave 2-min. Cobb tests of 2.75 to 4.0 grams. For well-sized stock, the tests were 0.30 to 0.20 gram.

In the unsized range, the gravimetric Cobb test does not give close duplication of tests results. It must be borne in mind, however, that this is not a *test* failure, but a *sizing* failure. Poor sizing varies all over the lot; the very fact that the amount of water absorbed in 2 min. varies before one's very eyes, is visual proof of this. Therefore, we did not work for checks in tests on unsized stock; but used an average figure obtained on

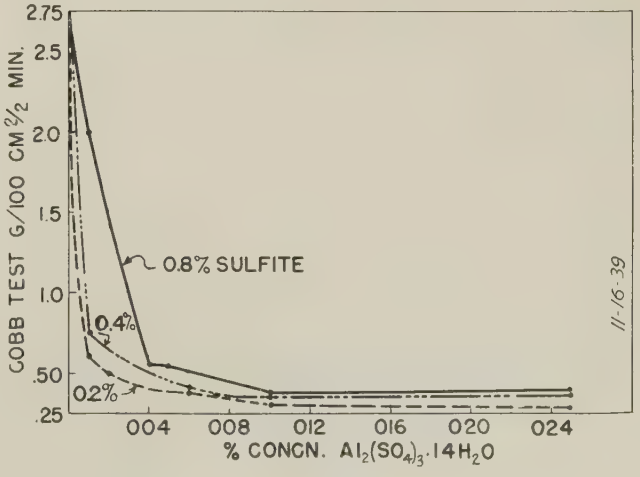


Fig. 2. Effect of stock consistency on sizing 1% rosin

unsized stock, of 2.75 grams, which was the starting point value on the curves in Figs. 2 through 8.

For sizing *harder* than that needed for clay coating, the test time would have been extended to 30 min., or to 4 hr., or even overnight to 16 hr., depending on the degree of sizing. Over the years the amount of water absorbed has been found to vary directly between $\sqrt{\text{time}}$ and $\sqrt[2.5]{\text{time}}$.

The elapsed times frequently used are:

	Test time	Ratio to 2 min.	Factors for calculating 2-min. Cobb test $\sqrt{Time}$	$\sqrt[2.5]{Time}$
Unsized or soft-sized stocks	30 sec.	0.25	0.5	0.575
Stock sized for clay coating	2 min.	1	1	1
Hard-sized stock	30 min.	15	3.87	2.95
Food containers (aqueous contents)	4 hr.	120	10.95	6.79
Food containers (aqueous contents)	16 hr.	480	21.9	12.36

With sizing tests such as the ink flotation test, the lowest in flotation tests values come, of course, with unsized stock, and in flotation tests numerical variations are less noticeable in the poor sizing range than in the good sizing range. But the *percentage* variation is large so that with ink flotation tests, too, an average figure must be used for tests on soft-sized stocks.

Chemicals. Aluminum salts, 10% solutions; corresponding acids, 5% solutions; papermaker's dry size, 3% solution.

Stock. Unsized sulphite beaten 1.5 hr. at 7.0% consistency. Just before the beatermen added size to the beater, sufficient stock was removed to make several laboratory runs.

Sizing the Stock.

1. One thousand eighty-five grams of sulphite stock at 7.0% consistency were diluted with tap water to a total of 19,000 ml. in a 5-gal. pail at 70°F. This gave a 0.4% stock suspension corresponding to the vat consistency.

2. Twenty-five and three tenths milliliters of 3% rosin size were added and stirred in with a hand paddle. This gave 1% rosin on fiber.

3. The desired amount of 10% aluminum salt was poured in from a graduate while the stock was stirred.

4. If acid was added, the 5% acid solution was poured in simultaneously with the aluminum solution while the contents of the pail were stirred.

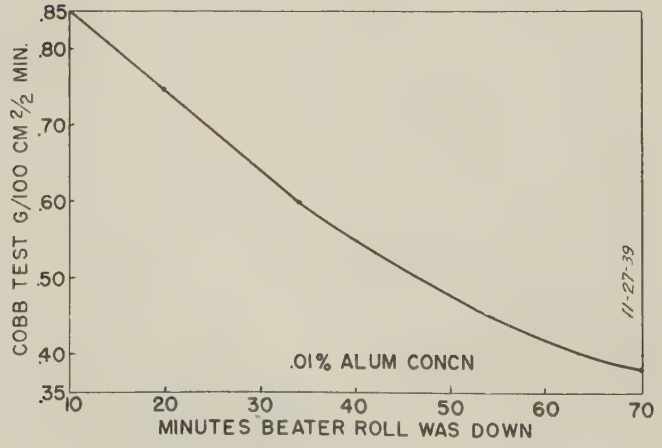


Fig. 3. Effect of beating time on sizing of sulphite 0.75% rosin

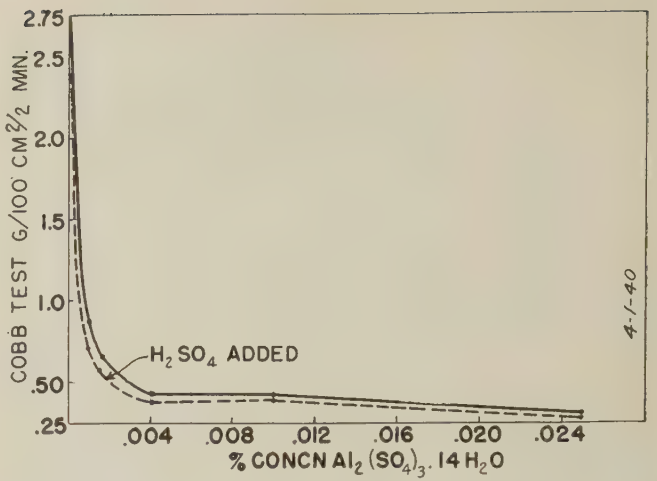


Fig. 4. Sizing of sulphite versus alum sulphate concn. 1% rosin

5. After standing 5 min., the pH of the stock suspension was taken colorimetrically.

6. Then 1750 ml. of the 0.4% stock suspension were removed from the 5-gal. pail for each handsheet.

The Noble and Wood sheet mold was empty except for water below the wire to prevent air entrainment.

The stock was poured directly into the empty sheet mold, and the sheet formed under suction.

The 7-gram handsheets so obtained were pressed separately between two wires, using an open felt and four weights on the Noble and Wood press.

After drying at 190°F., the sheets were cooled and the sizing tested for 2 min. by the Cobb test.

Choice of Vat Consistencies. There was one decided advantage in using the same vat consistency of 0.4% for both size precipitation and sheet formation. The sheet of stock could be formed directly in the Noble and Wood mold without further dilution with fresh or with white water. This eliminated some very undesirable variables.

The disadvantage was that at 0.4% consistency the evidence in Table IV indicated the sizing precipitate would not be entirely adsorbed by the stock. But since the 7-gram handsheets formed well in the mold at this consistency, better than they would at the higher value of 0.8%, the lower consistency was compared with the higher. Sizing results, as shown in Fig. 2, indicated that in handsheet work, 0.4% consistency would be satisfactory, and therefore, 0.4% consistency was used.

As pointed out by Egy (*17*), the need for absolute perfection in the handsheets is of course done away with when the gravimetric Cobb test is used in sizing research. With other testing methods that use the time of complete liquid penetration for the end point, small imperfections or pinholes seriously affect or invalidate the results. Therefore with other sizing test methods where the structure of the handsheet is critical, stock consistencies lower than 0.4% are necessarily used in the sheet mold. Price and Cameron (*33*), for example, formed their handsheets at 0.025%. At such low consistencies dilution with tap or white water becomes a problem that must be faced.

Effect of Beating Time. Using the above handsheet procedure, but only 0.75% rosin on the fiber to increase

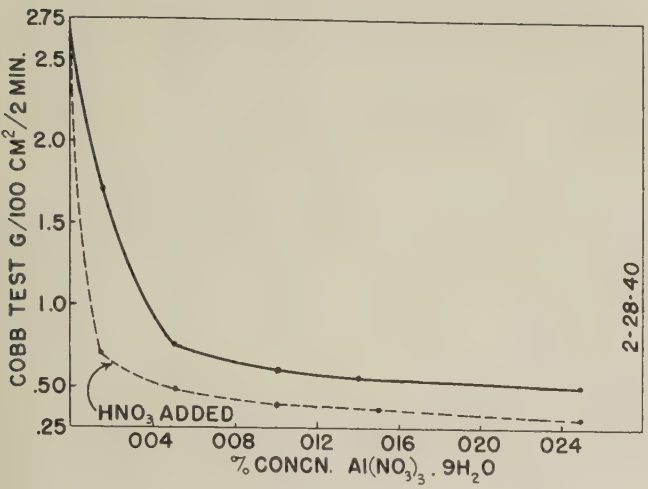


Fig. 5. Sizing of sulphite versus alum nitrate concn. 1% rosin

the sensitivity of the experiment, the effect of beating time on the sizing of an 1800-lb. standard beater load is shown in Fig. 3.

Increased beating time increased sizing, as manifest in the reduced Cobb test, quite sharply for the first hour, and then showed signs of leveling off. Because 1.5 hr. was the standard beating cycle in the mill, the sulphite, and later the groundwood stock used in the handsheets was taken from the beater at the end of 1.5 hr. beating time.

Using other sizing tests, W. S. Wilson (*43*) indicated in 1949 that beaten pulp is less well sized than unbeaten or slightly beaten pulp. Wilson's test methods involve equilibrium values and are not important from the viewpoint of the paper coater who is interested in the *rate* of water pickup by the coating surface and not the equilibrium pickup. Wilson's work has brought up an interesting point of contrast, however, between rate and equilibrium methods of testing paper sizing.

ESTABLISHING THE COORDINATE ROLE OF ALUM IN SIZING

Running up the Anion Coordinating Affinity Scale

As stated in the introduction, Thomas' (*40*) listing of the coordinate affinity of anions for aluminum runs from the least coordinated to the greatest in the following order: nitrate; chloride; sulphate; acetate; tartrate; citrate; citrate = oxalate; hydroxyl oxalate. The investigation centered on a comparison of other aluminum salts against standard papermaker's aluminum sulphate, $Al_2(SO_4)_3 \cdot 14H_2O$.

To establish the validity of the coordination theory, therefore, it was necessary to run along the row of aluminum salts in the order of the coordinating affinities of their anions.

It was natural to expect that the anions least strongly coordinated to aluminum would be the easiest to replace with anionic sizing materials and with cellulose, thus forming a successful sizing complex, as in the case of aluminum sulphate.

Then it would be essential to determine how high it was necessary to go along the scale of coordinating affinity before the native original anions refused to let go of the aluminum atom, refused to be replaced by cellulose or anionic sizing material—and sizing, in effect, blocked.

If some of the aluminum salts with anions more highly coordinated than the sulphate of regular papermakers' alum did not size paper, the coordination theory would be established. It was as simple as that.

The Alum Concentration-Sizing Curves

Using the above handsheet procedure and 1% rosin size on the stock, two curves were run for each aluminum salt.

One curve was run with the aluminum salt content of the 0.4% stock suspension varied from 0 to 0.025% of the total water and stock, taking whatever pH was obtained at each concentration of the aluminum salt.

This first run was followed by a similar set of experiments in which the pH was adjusted to the range 4.3 to 4.5 with acid whose anion was the same as that of the aluminum salt. For aluminum sulphate, sulphuric acid was used; for aluminum nitrate, nitric acid, and so on. In the case of the oxalate anion, the aluminum salt of the acid being insoluble, a change had to be made in this procedure. Aluminum sulphate was used to set the size and the effect of oxalic acid in amount sufficient to make the pH 4.3 to 4.5, was determined.

The results of these studies of aluminum salt concentration versus sizing effect are shown in Figs. 4 to 8. On each graph, the abscissa represents the per cent concentration of the aluminum salt in the hydrated form as purchased. The ordinate gives the amount of water absorbed as tested by TAPPI Standard T 441 m-45.

pH values for some of the runs without acid are given in Table V, and comparative molecular weights of the aluminum salts in Table VI.

Results with Weakly Coordinated Anions

Aluminum Sulphate. Starting with Fig. 4 for the regular papermakers' alum which is most familiar, it is evident that while sizing begins to be noted at a concentration of alum as low as 0.001%, sizing is not adequate until between 0.004% to 0.01% alum is present. At 0.025% alum, sizing is slightly better.

The addition of sulphuric acid in amount sufficient to bring the pH to 4.3 to 4.5 does very little to improve sizing with papermakers' alum at any given concentration of aluminum sulphate. But in observing this, it must be borne in mind that these experiments were run without the complicating contaminants present in reused papers and in mixed stocks. With these latter, mill experience has shown that the addition of acid to

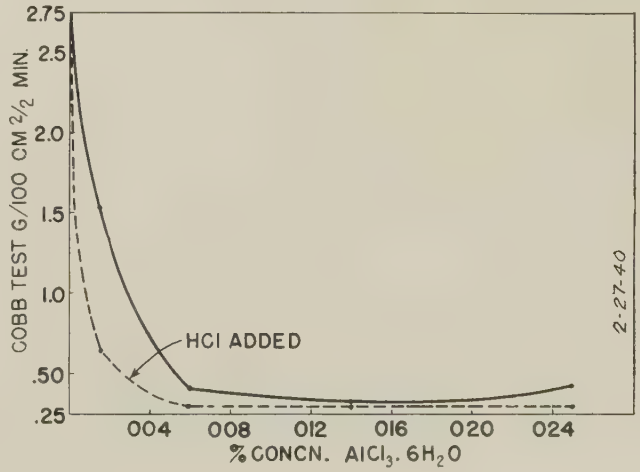


Fig. 6. Sizing of sulphite versus alum chloride concn. 1% rosin

lower pH, instead of using alum alone, will effect marked economies in alum consumption.

Table V. pH versus Aluminum Salt Concentration for Some Runs Without Acid

Hydrated aluminum salt concentration, %	*Colormetric pH of stock suspension*			
	Nitrate	*Chloride*	*Sulphate*	*Acetate*
0	7.1	7.1	7.1	7.1
0.0015	6.8	6.8	6.9	6.9
0.005	6.6	6.3	6.7	6.7
0.01	6.3	5.7	6.6	6.6
0.015	5.8	5.2	6.3	6.4
0.025	5.6	4.6	5.5	6.2

Aluminum Nitrate. Going to the aluminum salt whose anion is considered to have the least tendency to coordinate with aluminum ion, the results in Fig. 5 with aluminum nitrate are rather surprising. For since nitrate ion is the most weakly coordinated and hence easily replaced by anionic sizing material and by cellulose, it is almost to be expected that aluminum nitrate should give better sizing results than the sulphate.

But this is not the case. Not only is 0.005% aluminum nitrate needed before sizing begins to be observable, but the curve levels off at 0.025% aluminum nitrate without attaining full sizing.

In contrast to aluminum sulphate, however, the improvement in sizing by addition of nitric acid to aluminum nitrate is marked, and finally results in satisfactory sizing at 0.025% aluminum nitrate.

Aluminum Chloride. The use of aluminum chloride instead of aluminum sulphate for sizing has been reported by Duston (*16*) in the laboratory and Porter and Lane (*30*) in the mill. Since aluminum chloride is a highly acidic and versatile material, being used as acid catalyst, and as an astringent powerful enough to stop the flow of perspiration and even to remove warts, there was natural concern over its effects on screens, wires, and metal, in general around the mill. With the pH properly controlled, Porter and Lane report no corrosion difficulties. The utilization of aluminum chloride in place of alum is at present restricted by economic considerations.

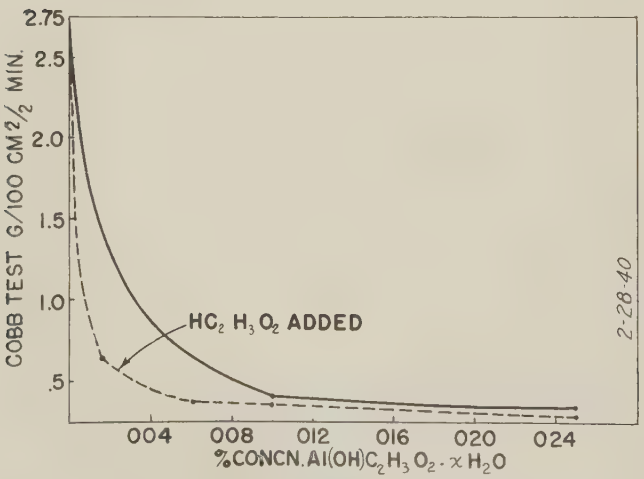


Fig. 7. Sizing of sulphite versus alum acetate concn. 1% rosin

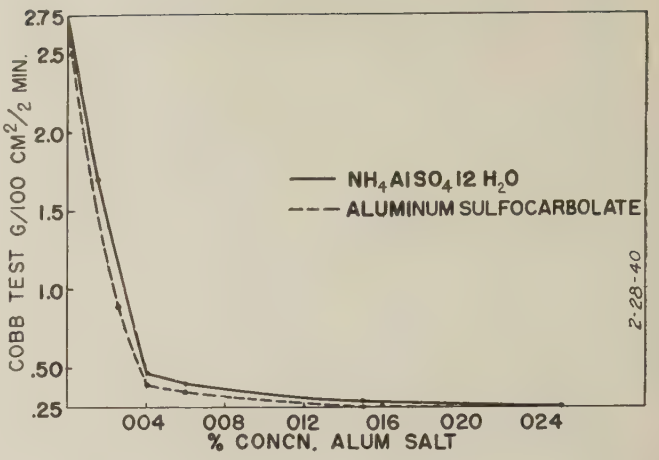


Fig. 8. Sizing of sulphite versus alum salt concn. 1% rosin

From Fig. 6 it is noted that aluminum chloride at 0.005% gives adequate sizing and comes to optimum sizing at 0.014%.

The addition of hydrochloric acid to lower the pH of the acid-salt combination down to 4.3 to 4.5, brings about marked improvement in sizing at the lower aluminum chloride concentrations.

This is in striking confirmation of the work of Setter and Mattson (*36*) on the electrophoretic effect of aluminum on the coagulation of soil colloids by aluminum chloride. Setter and Mattson found that when the amount of aluminum chloride was very *small*, enough acid to make the pH very *low* had to be used to make the soil complex lose its negative charge. When *large* quantities of aluminum chloride were present, the soil complex then became positive at pH values as high as 6.85.

Aluminum Acetate. Acetate was the first anion tested which had a coordinating affinity for aluminum higher than the coordinating affinity of sulphate for aluminum.

Aluminum acetate sizes well. Sizing is seen to be adequate at 0.01% aluminum acetate concentration. And with acetate as well as chloride, the addition of acid at the lower aluminum acetate concentrations greatly improves sizing (Fig. 7).

Ammonium Alum and Aluminum Sulphocarbolate. Two aluminum salts were run by themselves, without acid. They were:

1. Ammonium aluminum sulphate, or ammonium alum, which some old-time papermakers considered preferable to alum, so much so that they continued to use it despite its slightly higher price.

2. Aluminum sulphocarbolate, a material newly on the market around 1939, of interest because it had as-

Table VI. Comparative Molecular Weights of Aluminum Salts—Low Coordinating Anions

Aluminum salt	$Al(NO_3)_3 \cdot 9H_2O$	$AlCl_3 \cdot 6H_2O$	$Al_2(SO_4)_3 \cdot 14H_2O$	$Al(OH)(C_2H_3O_2)_2 \cdot xH_2O$	$(NH_4)Al(SO_4)_2 \cdot 12H_2O$
Molecular weight	375.14	241.44	594.33	About 251	453.32
Aluminum, %	7.18	11.2	9.08	10.75	5.94
Equivalent grams	1.26	0.81	1.0	0.84	1.53
Mols anion/mols Al	3	3	1.5	2	2

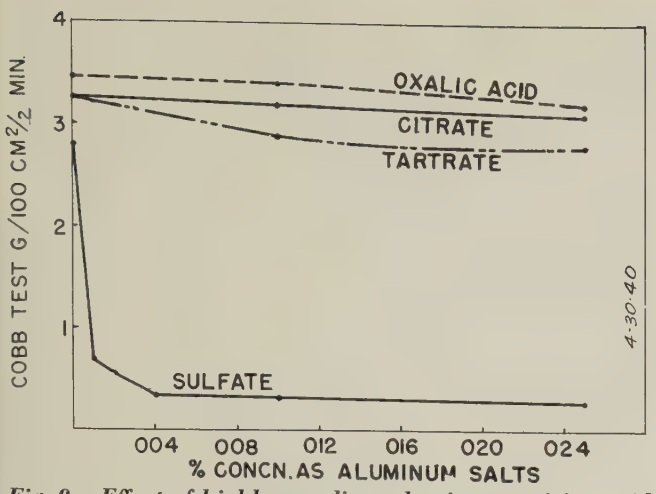


Fig. 9. Effect of highly coordinated anions on sizing-acid added 1% rosin

tringent properties which reportedly developed at a higher pH than aluminum chloride.

As is shown in Fig. 8 both of these less common materials were exceptionally good sizing agents; with them, sizing was adequate at concentrations of 0.006% and very good sizing was obtained at 0.015% concentrations of these aluminum salts.

Significance of Results with Anions of Lower Coordinating Affinity.

(1) Effect on Anions and Acids on Coordination by Aluminum.

The laboratory work on handsheets indicated that there was a group of anions in the lower part of Thomas' scale of coordinating affinity, which would permit the sizing of paper by means of their aluminum salts. These were: nitrates, chlorides, sulphates, and acetates.

In the lower aluminum salt concentrations, addition of the acids of corresponding anion to reduce the pH to 4.3, markedly improved the sizing obtained with nitrate, chloride, and acetate of aluminum. In this work, addition of sulphuric acid did not greatly improve the sizing effect of aluminum sulphate which is papermakers' alum. But this last is a point that should be checked before coming to the definite conclusion that aluminum sulphate differs from the other similar aluminum salts in that one respect. If sulphate does so differ, we should look for an explanation in the work on sulphate ion by Collins, Davis, and Rowland (*11*), by Wilson (*44*), and by Gorham and Thode (*19*).

With the obvious exception of OH, inorganic anions are not highly coordinated and in *normal* amounts do not block sizing. But Wilson (*44*) has presented evidence that *large* quantities of sulphate and other inorganic anions are detrimental to sizing. Collins, Davis, and Rowland (*11*) find that sulphate anion reduces the electrophoretic mobility of alumina flocs formed from aluminum chloride, while Gorham and Thode (*19*) have shown that excessive sulphate ion decreases net surface potential.

Obviously as aluminum ion is taken out of the system by the fibers to which it is affixed, sulphate ion builds up in the white water. A superabundance of sulphate for coordination to aluminum becomes available, and the coordination of rosin and fiber by aluminum ion is correspondingly lessened.

Sizing therefore is adversely affected when the sulphate content of the sizing system becomes too high. So it is possible that the good effects of lowering pH by addition of sulphuric acid are offset by the excessive tendency of the SO_4 ion to coordinate, as Wilson (*44*) has already pointed out in only slightly different terms.

(2) The Aluminum Salt Concentration-Sizing Curves. The basic similarity of all the aluminum salt concentration-sizing curves shown in Figs. 4 to 8 is conclusive.

From the curves, it was clear that for handsheet sizing at vat consistency, the concentration of aluminum salt should range between: 0.005% for pH adjusted to 4.3 to 4.5 with acid, and 0.020% with aluminum salt alone.

At this point it is interesting to compare these figures with mill conditions:

	Beater	*Vat (nothing added)*
Total weight, lb.	25,000	...
Dry fiber, lb.	1,750	...
Dry size, lb.	30	...
Dry alum, lb.	20	...
Dry fiber, %	7	0.4
Dry rosin, %	0.12	0.007
$Al_2(SO_4)_3 \cdot 14H_2O$, %	0.08	0.00465

Perhaps the most surprising and most detached confirmation of the curves in Figs. 4 to 8 and our consequent establishment of the range of alum concentration necessary for sizing, has been found in subsequent work on flotation treatment of white water by Poor and Whitenight (*29*) in 1942. Poor and Whitenight studied the range of alum concentrations which would give optimum clarity of white water. In doing this, they used 0.02% clay suspension to simulate white water; and for clarification, along with the alum they used 0.002% myristic acid soap.

In this work on clarification Poor and Whitenight established an optimum alum concentration of 0.016% to 0.025% $Al_2(SO_4)_3 \cdot 14H_2O$. This gave maximum clarity, so they thought, because at this alum concentration the aluminum myristate was completely insoluble; and yet the aluminum soap did not precipitate so fast that the clay was not absorbed. Similar reasoning might of course be applied to the precipitation and coordination of rosin size.

The curves in Fig. 4 also were found to bear striking

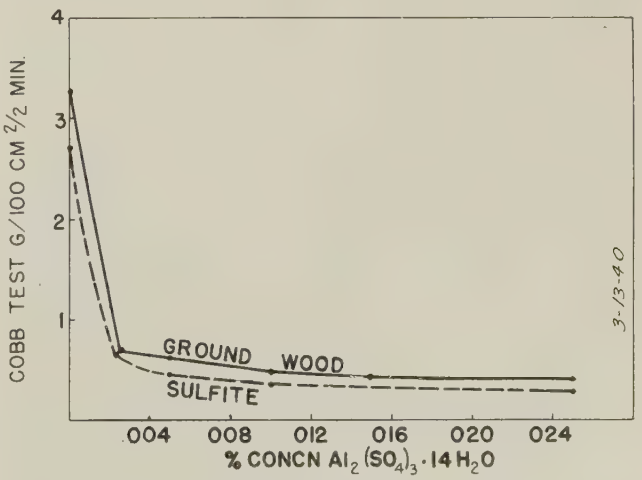


Fig. 10. Negligible effect of CO_2 on sizing when % CO_2 = 0.025% alum 1% rosin

analogy to the results on coagulation by alum published in 1953 by Thode, Gorham, and Atwood (*39*). Following the work of Setter and Matson (*36*) in 1935 and Collins, Davis, and Rowland (*11*) in 1942, Thode, Gorham, and Atwood related the coagulation of the material under study, to the electrophoretic effect of aluminum salts. They found that rosin size precipitated as a complex with a *positive* charge under these equivalent conditions:

10 p.p.m.—0.001% $Al_2(SO_4)_3$
or
17 p.p.m.—0.0017% $Al_2(SO_4)_3 \cdot 14H_2O$ (alum)

although Kumler (*20a*) reports that later results indicate some sizing is obtained while the precipitate carries a negative charge, perhaps through mechanical entrapment.

In studying tall oil rosin acid monolayers in reaction with aqueous $KAl(SO_4)_2$, Ekwall and Bruun (*18*) worked over so wide a concentration of Al ions that the Al ion concentration was expressed in negative logs. Their data have appeared since this paper of ours was presented before TAPPI. Reduced to per cent alum concentration, Ekwall and Bruun's figures for maximum interaction between rosin substrate and aluminum ion is equivalent to: at pH 4.3, 0.03% $Al_2(SO_4)_3 \cdot 14H_2O$.

Rudolfs and Nemerow (*35*) have recently found that above pH 4.0, a minimum concentration of about 0.02% alum is effective in preventing slime growth.

This persistent affirmation of the narrow range of 0.015 to 0.030% for effective alum concentration leads to what Bondi (*2*) has termed "a cabalistic belief in a number."

(3) Effect of Anions on Coagulation. The failure of the aluminum salt with the least firmly coordinated anion, the nitrate, to size as readily as the more highly coordinated sulphate or acetate, immediately brings to mind Miller's (*24*, *25*) work on the *coagulating* power of the anions. For Miller found the monovalent chloride ion to be not so effective in coagulating aluminum hydroxide as was divalent sulphate ion. Also, Black, Bardwell, and Graham (*1*) have reported that the presence of sulphate ions broadened the zone of rapid floc formation when alum was coagulated with sodium hydroxide. At 125 p.p.m. of sulphate ions, added as sodium sulphate, alum precipitated very rapidly in the pH range 5.0 to 7.0. In equivalent alum concentration

125 p.p.m. $S\bar{O}_4$ ion $\simeq$ 0.025% $Al_2(SO_4)_3 \cdot 14H_2O$

in addition to the sulphate already present in the alum solution.

Thus it may be that superimposed upon the relative coordinating tendencies of the anions attached to aluminum, is their relative tendency to coagulate and throw down the insoluble alum-rosin sizing precipitate.

In water coagulation research, the pH of acidic aluminum salts alone, without rosin, is *raised* until alum floc is precipitated, *greater* precipitation occurring as the pH is *raised*.

In the case of rosin sizing, on the other hand, insoluble precipitation, and coordination of cellulose and size by aluminum, increases as the pH is *lowered* by addition of acidic aluminum salts and acid. In water clarification it is a triumph to get good coagulation at *low* pH; in paper sizing, it is a triumph to get good results at

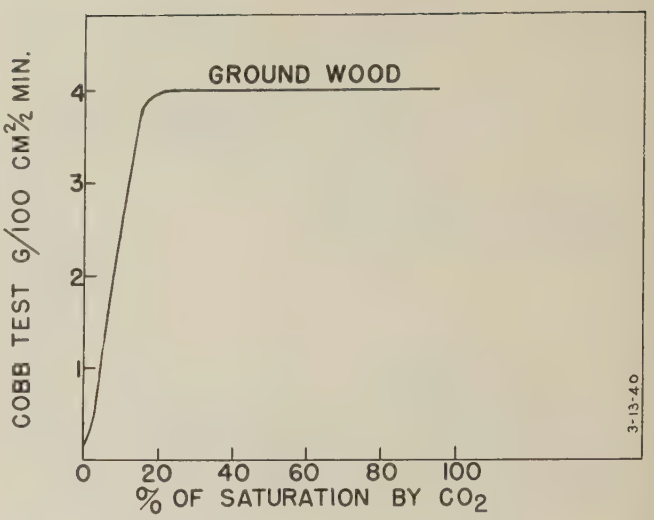


Fig. 11. Destruction of rosin & alum sizing by CO_2. 1% rosin & .025% alum

high pH. This difference must be borne in mind when attempting to apply in the paper field, results on alum studies made in the water field.

Contrasting Behavior of Strongly Coordinated Anions

Aluminum Tartrate and Citrate. The anions, tartrate and citrate, were stated by Thomas to be highly coordinated to aluminum.

The water-soluble salts, aluminum tartrate and aluminum citrate, yielded aluminum salt concentration–sizing curves which were entirely different from those derived when the sulphate and other low-coordination affinity anions were used to set rosin size.

As seen in Fig. 9, aluminum tartrate and aluminum citrate failed to produce sizing with and without addition of the corresponding acids to reduce the pH to 4.3.

Concentrations of 0.5 and 1.0% of the salts, in addition to those concentrations indicated on the curves, likewise failed to produce sizing in the case of these highly coordinated tartrates and citrates.

The Oxalate Anion. Since aluminum oxalate is insoluble in water, to determine the effect of the highly coordinated oxalate anion it was necessary to resort to the use of the water-soluble form, oxalic acid.

Accordingly, a curve was run using standard aluminum sulphate as the aluminum salt, and after the size was set with alum, sufficient oxalic acid was added to make the pH 4.3.

As apparent in Fig. 9, the oxalic acid is so highly coordinated to aluminum, that its presence effectively prevents sizing.

The Effect of CO_2 and the CO_3 or $H\bar{C}O_3$ Anion. (1) Previous Concepts About Calcium and Carbonate. Once the importance of the coordinating affinity of the anion for aluminum was so strikingly established, the question naturally was raised, where does the carbonate anion fit in this picture? For the position of carbonate in the scale of coordinating affinity was not given by Thomas (*40*).

It had of course long been known that sizing with rosin or wax in the presence of calcium carbonate presented great difficulties.

At first the calcium ion had been considered to be the cause for poor sizing. Calcium was thought to react

with the resinate, thus forcing formation of calcium resinate instead of aluminum resinate. It was assumed that calcium resinate so formed would not fully size the fibers. But this idea of formation of calcium resinate was exploded by Sutermeister (*37*), who showed that when the calcium was present as $CaCl_2$ or CaO_2H_2, normal sizing with aluminum sulphate and rosin could be obtained. This threw suspicion upon calcium carbonate, and removed suspicion from calcium as the deterrent to sizing.

Next, the failure to obtain sizing in the presence of calcium carbonate was thought to be due to the impossibility in the presence of calcium carbonate of going down to a pH low enough to set the size. Calcium carbonate begins to give off carbon dioxide before the pH gets down to 4.7 to 4.3. To get full sizing at pH 6.8 to 6.5 where calcium carbonate remains intact, is not possible with rosin or wax size.

In view of the results of Sutermeister and mill experience with carbonate-filled shavings, it had long been our thought that carbon dioxide itself might have a deleterious effect on rosin sizing. Consequently the $\overline{CO_3}$ anion was brought into the coordination picture.

(2) Studying the Effect of CO_2 and $\overline{CO_3}$ or $\overline{HCO_3}$ on Sizing. The equivalent values of the chemicals utilized in determining the coordinate affinity of $\overline{CO_3}$ for aluminum are given in Table VII.

(a) Low concentrations of CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$.

In this work, the calculated amount of $NaHCO_3$ was added to 19,000 ml. of tap water in a 5-gal. pail. Then the calculated amount of 5% sulphuric acid was run in and allowed to react thoroughly with the bicarbonate before the beaten unsized paper stock was added. Next rosin size and 10% alum solution were poured in as usual to size the fibers in the pail. And finally the pH was adjusted with acid to pH 4.3 to make sure the $NaHCO_3$ was converted to CO_2 or H_2CO_3, and to ensure the optimum sizing.

The first set of experiments was run as usual on beaten sulphite. Then the work was repeated on groundwood, when it was found that the arrangement of mill orders would make beaten sulphite unavailable for an appreciable time.

In the first set of experiments an alum concentration sizing curve was established as before, but present in the 0.4% stock suspension during each test there was an amount of CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$ (we know not which) equivalent to the alum concentration used in that test.

Results shown in Fig. 10 indicate that when CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$ is present merely in concentrations equivalent to the amount of alum necessary for sizing, the effect on sizing is negligible.

(b) High concentrations of CO_2, $\overline{CO_3}$ or $\overline{HCO_3}$. Because mill experience had indicated that CO_2, $\overline{CO_3}$ or $\overline{HCO_3}$ *must* have an adverse effect on sizing, however, the question was persistently pursued. Further experiments were run only on beaten groundwood stock, as beaten sulphite stock was not available at that time in the mill.

In this second set of CO_2, $\overline{CO_3}$ experiments the per cent alum concentration was maintained at the comfortably optimum concentration of 0.025% and the amount of CO_2 or $\overline{CO_3}$ widely varied. For the first point on the curve shown in Fig. 11 an amount of $NaHCO_3$ was taken which would correspond to 95% saturation of the water present by CO_2, after the latter was liberated by sulphuric acid. When that intuitive persistence was rewarded by the fact that no sizing at all was obtained in the presence of this high concentration of CO_2 or $\overline{CO_3}$, lower values were also set up and tested and the curve of Fig. 11 resulted.

Examination of the curve indicates that sizing begins to be adversely affected by CO_2 or $\overline{CO_3}$ at about 5% of CO_2 saturation, and that sizing is destroyed or prevented at approximately 15% of CO_2 saturation. Thus the second set of tests showed that the adverse effect of CO_2 or $\overline{CO_3}$ began to show up at values of CO_2 concentration just above those where the first set of experiments, with low concentrations of CO_2 or $\overline{CO_3}$, left off.

The values of the concentrations of CO_2 in terms of CO_2 or of $CaCO_3$ are:

	% Concn. CO_2 by weight	*Equiv. % $CaCO_3$*
5% of CO_2 satn.	0.0085	0.019
15% of CO_2 satn.	0.0255	0.057

As was the case with other highly coordinated anions, increasing the alum concentration in this case to 0.05 and 0.1% did not restore sizing in the presence of CO_2 present to 95% of its saturation value.

(3) Effect of Concentration of CO_2 and Carbonates Upon Coordination: It is generally accepted that the equilibrium $CO_2 <\!\!-\!\!> H_2CO_3$ goes to the left, with relatively few H_2CO_3 molecules being present in solution. Two OH groups on one carbon atom generally make for instability in a compound, so that "carbonic acid" is thought to consist, in actuality, of a solution largely of CO_2 in water. Of course it may be considered possible that as $\overline{CO_3}$ or $\overline{HCO_3}$ is removed from solution by coordination with aluminum, more H_2CO_3 will then be formed, and this in turn coordinated. CO_2 itself may be coordinated; that question has not been resolved.

The difference in behavior between CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$, and the other highly coordinated anions such as tartaric and citric acids is more quantitative than qualitative.

Although the minimum amounts of tartrates, citrates, or oxalates to affect sizing has not been established, these more highly coordinated anions block or prevent sizing at any normal concentration of the aluminum-organo salt. On the other hand, CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$ being coordinated to a medium or borderline extent, behave as if greatly affected by the quantity of CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$ present. Lower quantities of the carbonates do not block sizing, higher quantities do.

It is perhaps because of this very "now it blocks it, now it doesn't," behavior that the adverse effect of CO_2, $\overline{CO_3}$, or $\overline{HCO_3}$ on alum-rosin sizing has not been definitely pinned down long before this.

Another factor which possibly affects these results is the point that the more highly coordinated organic

Table VII. Equivalents and Solubilities

	$Al_2(SO_4)_3 \cdot 14H_2O$	$CaCO_3$	H_2SO_4	$NaHCO_3$	HCO_3^-		CO_2
Molecular weights	594.41	100.09	98.08	84.02	61		44
Equivalent to 1 g. CO_2	2.25	2.28	2.23	1.915	1.39		1.00
Solubility in 100 ml. H_2O, g.	...	0.0015	...	9.5	...		0.17
Solubility in 19,000 ml. H_2O, g.	...	0.1900	...	181	...		32.3
Grams for every 0.001% alum in 19,000 ml. H_2O	1.9	...	+ 0.94	+ 1.62	...	→	0.845
Grams for 0.025% alum in 19,000 ml. H_2O	4.75	...	+ 2.34	+ 4.05	...	→	2.12
Grams for 0.025% alum and CO_2 satn. in 19,000 ml. H_2O	4.75	...	+36	+61.7	...	→	32.3

anions, except for oxalic acid, were used alone to set the size. In the case of CO_2, CO_3^-, or HCO_3^-, as with oxalic acid, aluminum sulphate was added to set the size in the presence of the CO_2, CO_3^-, or HCO_3^-.

However this may be, Charriou (*5*), has, as stated before, found that while nitrate, chloride, or acetate will not leach yellow chromate ion out of an aluminum-chromate precipitate, bicarbonate and carbonate will do so. This work of Charriou therefore places the coordinating affinity of bicarbonate and carbonate about where the sizing work reported in this paper places them. The sizing results with sulphate do not so agree with those of Charriou.

Significance of Results with Highly Coordinate Organic Anions and with CO_2,CO_3^- or HCO_3^-.

The importance of the Thomas concept that in rosin sizing the linkage of rosin and fiber through the mechanism of coordination is essential, is brought out by the behavior of the highly coordinated anions.

(1) Blocking Effect of Highly Coordinated Anions. The difference in sizing effect between aluminum salts with anions of low coordinating affinity, such as nitrate, chloride, sulphate, and acetate, and aluminum salts with anions of highest coordinating affinity such as citrate, tartrate, and oxalate is clear cut. The effect of high coordination is to block sizing.

The difference between the sizing effects when CO_2 or carbonates are absent or present is less striking, because the blocking effect of CO_2 or carbonates varies with their concentration. CO_2 and H_2CO_3 are small molecules, and it is the *large* organic molecules that are highly coordinated to aluminum. Even with CO_2 or carbonates, however, undesirable preferential coordination of carbonate anions rather than of rosin and cellulose is seen to occur.

It is obvious that the anions which will be coordinated to aluminum in preference to rosin are rank poison to the sizing process, and should not be present in amounts greater than the sizing system can tolerate.

Other industries are more fortunate in that they may take advantage of this high coordination of certain anions in a profitable way. Knowledge of the blocking effect of organic anions has long been used in the tanning industry for stripping chrome tanning agents off tanned leather, using solutions of highly coordinated salts such as sodium potassium tartrate (Rochelle salts).

(2) Fugitive Sizing: Fugitive sizing is the term indicating a condition wherein paper is fully sized with rosin at the time of manufacture, and then found to be unsized when tested again a day or a week later. Carbon dioxide in hot paper rolls has long been suspect as a contributing cause to this dry destruction of sizing. Gradual coordination of carbon dioxide or other anion to displace rosin from the aluminum is therefore likely to be found the mechanism whereby rosin sizing becomes fugitive.

(3) The Effects of Highly Coordinated Anions on Electric Charge: It was shown by Setter and Matson (*36*) in 1935 in electrophoresis experiments, that the aluminum ion in aluminum chloride functions in the coagulation of soil colloids by making the suspended soil complex lose its negative charge. On further addition of aluminum chloride, the soil complex becomes electropositive.

Ostwald and Lorentz (*28*) considered that sizing should be carried out near the isoelectric point of the rosin-alum complex. With insufficient alum, rosin and fibers were negatively charged and repelled each other; with too much alum, rosin and fibers were positively charged and also mutually repelled each other.

Collins, Davis, and Rowland (*11*) carried out visual and microelectrophoretic studies on alumina, on rosin particles precipitated by acids, and on rosin size precipitated by aluminum and sulphate aluminum chloride, in part to explore the theory of Ostwald and Lorentz. They found that rosin had a markedly negative character, but that no inflection points occurred that might represent a zone of isoelectric conditions. The change in migration from positive to negative pole for rosin size–alum precipitates occurred near pH 5.8.

Similarly, Thode, Gorham, and Atwood (*39*) found in 1953 by electrophoresis measurements that the original negative potential value of rosin changed rapidly to positive upon small additions of aluminum sulphate.

But in the presence of some highly coordinated anions suggested by unpublished work of Woodberry, namely citrate and ferrocyanide, Gorham and Thode (*19*) found that a negative potential value of rosin was maintained, and sizing was destroyed.

The maintenance of the negative electrical charge on rosin in the presence of a highly coordinated anion may be explained by A. W. Thomas' picture of the role of aluminum in sizing. To become positively charged, it seems to be necessary for the originally negative rosin and cellulose complexes to be taken into the sphere of influence of the positive aluminum ion. The rosin and cellulose complexes can be taken into the positive sphere of influence of the aluminum ion only if they can replace the anions, such as chloride or sulphate, that are already there and coordinated to aluminum.

Obviously, there are some organic anions so highly coordinated to aluminum that neither rosin nor cellulose can replace them. Therefore cellulose and rosin will remain outside the positive sphere of influence of the aluminum ion in such cases, and the cellulose and rosin will retain their negative charge. Furthermore, if anions with a high coordinating affinity such as cit-

rate or oxalate, are added to a positive aluminum-rosin-fiber complex already formed, the anions with high coordinating affinity will replace the rosin and fiber in the aluminum complex. This will in effect cause rosin and fiber to resume their original negative charge.

(4) Production of Highly Coordinated Anions Under Hot Weather Conditions in the Mill: Through the discovery of the blocking effect of anions highly coordinated to alum, there is now a logical explanation of one of papermaking's most annoying mysteries, namely, hot weather sizing troubles.

It scarcely need be pointed out that during hot weather, bacterial action is at its height. Lewis and Davis (*21*) state that several species of bacteria have the power to ferment cellulose. When the fermentation is aerobic and oxidizing, they find there is considerable amount of carbon dioxide evolved, following extensive first-stage hydrolysis of the cellulose by bacterial action. Lewis and Davis indicate that as much as two thirds of the cellulose attacked by bacteria may end up as carbon dioxide; the other one third is accounted for by some mucilaginous oxycellulose which has acidic characteristics.

On the other hand, according to G. A. Cruickshank (*13*), it should be emphasized in this discussion that "None of the recognized slime formers, as far as we know, is capable of attacking cellulose. This does not mean that cellulose-attacking organisms are not present in mill systems. It is believed they are present and are a potential source of fiber degradation, particularly in storage of pulp. However, there is no definite information as to the extent of such degradation. In any case it is necessary clearly to differentiate between the production of carbon dioxide by slime bacteria which utilize preformed sugars in the mill system, and that by the cellulolytic organisms which produce carbon dioxide directly from cellulose.

"The production of citric acid by certain strains of species of black *Aspergilli* is well known. At the present time practically all of the citric acid manufactured is produced by fermentation of sugars, principally sucrose. The pH of the fermentation is between 1.6 and 3.0 to favor the production of citric acid and suppress the production of oxalic acid. There are several patents in the field, the earliest being issued to Wehmer in 1893. . . .

"Oxalic acid is not commercially produced by fermentation for economic reasons but such a fermentation does occur as previously noted of the *Aspergillus niger* group at pH levels greater than pH 3.0.

"Butyric fermentation is conducted in the absence of oxygen and probably does not occur in paper mills.

"Gluconic acid has been produced by bacteria, notably species of *Acetobacter* and *Pseudomonas*. However, commercial production is principally by action of certain species of *Aspergillus* and *Penicillium*.

"Lactic acid is produced industrially by the fermentation of carbohydrates, the bacteria concerned being species of *Lactobacillus* and *Leuconostoc*. The process is microaerophilic or anaerobic in character."

Thus out of the three organic acids studied in this paper which are so highly coordinated to aluminum that they destroy sizing, two, namely citric and oxalic acid, may be produced from common sugars by bacterial fermentation. Tartaric acid is produced from the lees of fermented grapes (grape sugar).

The other organic acids which Cruickshank indicates may be produced by fermentation, have not been studied here. But as Thomas (*40*) has pointed out, large organic anions tend to be highly coordinated to aluminum. So it would not be surprising to find that these other acids or some of them also will adversely affect sizing.

The main objectives of bacteria, yeast, and fungi in a paper mill appear to be the creation and accumulation of troublesome visible slime to dirty up the sheet and cause breaks. There may be another equally troublesome objective to create amounts of invisible carbon dioxide and organic acids sufficient to prevent or destroy sizing.

Obviously the presence of calcium carbonate on the fibers and in the water adds to the carbon dioxide potential in the sizing system, in cold weather as well as in warm.

(5) Production of Highly Coordinated Anions in the Pulp Mill.

During the manufacture of paper pulp from wood cellulose many complex organic chemicals are formed, including the production of organic acids and of lignosulphonic acid.

Marked differences in the ease of sizing of various pulps have usually been ascribed to the presence or absence of natural resins which themselves have sizing power.

According to the coordination theory, the reverse viewpoint may also hold true, i.e., a pulp may be difficult to size not because it lacks natural resins, but because in pulping the fiber, organic materials with high coordinating tendency have been left in the pulp, and sizing thereby blocked to more or less extent.

Structure of Coordinated Anions and of Cellulose

Tabulation of Anions. The two-dimensional structures of the anions with which these experiments have dealt, and of cellulose and abietic acid (rosin) are shown below. The anions are arranged in ascending order of their coordinating affinity to aluminum, as given by Thomas (*40*).

With the exception of the reverse position of sulphate and acetate, the coordinating affinity of the anions for aluminum increases with the number of available OH groups, and with the size of the molecule.

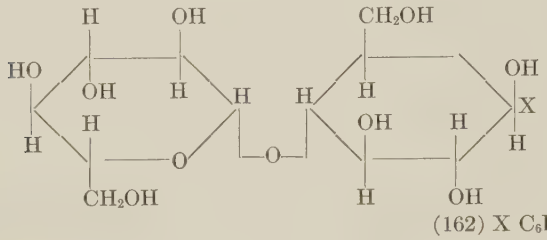
In a recent study, Swanson and Hemstock (*38*) have rated the sodium salts of several of these anions, as well as some others, for their dispersing ability when added to clay slips. As an interesting comparison, their ratings for dispersion of clay are included in the table of anions. For, with the exception of oxalate, the anions which are highly coordinated to aluminum, such as citrate, *do not* size paper and *do* disperse clay; while the one anion in their tabulation which is *not* highly coordinated to aluminum, sulphate, *does* size paper and *does not* disperse clay.

Cellulose. Cellulose, a sizable molecule even before its polymerization is considered, and which contains several available OH groups, falls in with the pattern of large and highly coordinated organic anions.

Abietic Acid = Rosin. A glance at the structure of the abietic acid in rosin shows that there is only one COOH group for coordination to aluminum. In view

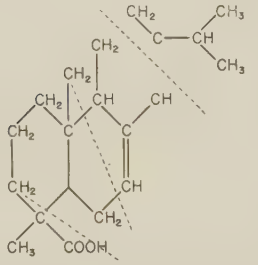
of the importance of coordination stressed in this paper, despite the large size of the abietic molecule such a condition is almost frightening! Therefore it is not surprising to find that some years ago researchers in the field of engine sizing developed a method for increasing the number of available OH groups on abietic acid; and that this research led to commercial production of a new type of rosin size.

Cellobiose
(Haworth) (*20*)



(162) X $C_6H_{10}O_5$

Abietic acid
(Conant and Blatt)
(*12*)



302.44 $C_{20}H_{30}O_2$

More Highly Coordinated Fortified Rosin Size. One commercial high-bonding size described by Wilson (*44*) has been available since 1943; and others have come into the market during the last five years.

In these fortified rosin sizes, maleic acid or another dienophile is reacted with the double bonds in abietic acid. The anhydride ring is opened up with sodium hydroxide.

Thus instead of the *one* OH group available in abietic acid for coordination to aluminum, in fortified rosin size there is a percentage of molecules that have *three* OH groups available.

Commercial applications in the paper mill now commonly indicate that when properly utilized, any ordinary degree of sizing may be attained by using fortified rosin size in amounts only half to two-thirds that required when using ordinary rosin size.

Furthermore, when sizing difficulties crop up in hot weather, it is reported to be possible to overcome poor sizing by increasing the amount of fortified rosin size. With standard rosin size, such an upward adjustment of the amount of size rarely succeeds in restoring sizing to desired levels.

A ready explanation for the occasional failure of even increased amounts of ordinary rosin size to work in hot weather, is afforded by the assumption that bacteria have been at work producing highly coordinated anions such as citrates or citric acid. These we have seen will block all sizing with ordinary rosin size.

Then the success of fortified size upon increased addition in hot weather would be explained by its increased coordination affinity for aluminum. The increased coordinating affinity must make it possible for the fortified size to compete successfully for aluminum with the citrate or other organic anions which bacteria have formed. This quantitative effect corresponds, albeit in reverse, to the quantitative effects discovered in the case of relative coordinating tendencies of carbon dioxide and ordinary rosin size.

APPLICATION OF RESULTS TO MILL PRODUCTION

The three points brought out in this investigation which seemed to be particularly applicable in the mill were: (1) the increase in efficiency of size precipitated on the fiber at high dilution; (2) control of alum concentration in the vats where the sheet was formed; and (3) holding the degradation of cellulosic material by bacteria, molds, fungi, and enzymes to a minimum by keeping the system clean; the object of this is to prevent the formation of organic anions so highly coordinated as to block sizing.

Precipitation of Rosin Size at Vat Consistencies

Over the years, beater size consumption in our board mill had averaged 1.8% on air-dry fiber ±0.1%.

Although headbox sizing was regularly practiced in many mills, our investigation of it was never successful. Precipitation of the size on the fiber at 0.4% stock consistency was not complete, hence the hoped for reduction in size consumption never materialized. Furthermore, that rosin which failed to be attached to the fiber rapidly filled up the felts and caused a great deal of foam. While not disastrous, these experiments were not popular in the mill. We did not seem to meet Robinson's (*34*) estimates, that while laboratory handsheets retained only 40% of the size, mill runs retained 80 to 90%.

From the laboratory work it was evident that had we been able to precipitate the size on the fibers at 1 or 2% stock consistency, results might have been nearer ideal. But since there was no spot in the system where stock consistency was controlled to 1 or 2%, precipitation of rosin size on the fiber at 1 or 2% consistency was never tried.

The practice of adding size streamwise was much easier to control than sizing in the beater. Therefore we added rosin size in a stream before the jordan. At the 4% consistency at which it was later precipitated by alum, we were never able to reduce below 1.8% rosin and still maintain sizing controlled at a Cobb test of 0.25 to 0.30 gram per 100 sq. cm. per 2 min.

Alum Control

The effective range of alum concentration was so clear, as shown in Figs. 4 to 8, that alum control was an obvious step.

It had been stated by Booth (*3*) the fact that there was no simple reliable test for alum as easy to make as a pH determination, was the reason for lack of information as to the alum content of the papermaking system.

A spot test for alum had been developed by Donnally (*15*) at the start of this work at Lowe Paper Co. It was adapted from a test for alumina published by Morgan (*27*), and it used as color indicator the hematein mentioned by Booth (*4*). Results depended upon the appearance of a purplish color when 0.015% $Al_2(SO_4)_3 \cdot 14H_2O$ was present.

The test for alum was very simple. Since 0.015% alum was a sufficiently high concentration to maintain in the cylinder vat, any sample showing a purplish color in the spot test contained enough alum for sizing. If no color appeared, the flow of alum was increased until the color indicating 0.015% alum did appear.

Any sample showing a purplish coloration in the initial test was then diluted with an equal quantity of water, to cut the alum concentration of the sample in half. If a purplish coloration appeared in this diluted sample, it indicated that the original alum concentration before dilution was at least 0.03%, and so the flow of alum into the system was decreased.

The desirable standards for alum control by this method were set as follows:

1. A purple color should appear in the initial spot test, indicating an alum concentration of 0.015% or more.
2. No purple color should appear in the second test made at dilution to 50% of original content.

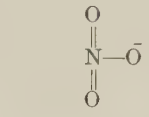
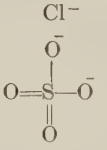
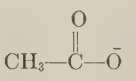
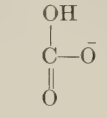
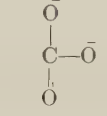
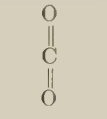
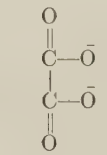
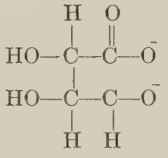
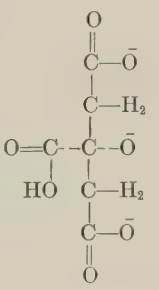
In this way the alum concentration was maintained between 0.015 to 0.02%, which proved to be satisfactory for the cylinder vats. Once enough alum was present in the system, the vat pH was adjusted with sulphuric acid.

This ready control of alum was very popular in the mill with the machine tenders during the early war years, and they kept it up with good results on both sizing and sheet formation. But finally allocation of alum resulted in the mill being forced to use an alum of high iron content that gave a black tinge to the solution so that the color spot test could not be used; and it has never been resumed.

Minimizing Degradation of Cellulose

In a paper which has attained this length it would be

Table VIII. Two-Dimensional Structures

Material	*Sizing effect (+ = sizing)*	*Ability to disperse clay*	*Structure*	*Molecular weight*	*Formula*
Nitrate anion	+	(Not given)		62.01	$N\bar{O}_3$
Chloride anion	+	(Not given)	Cl^-	35.46	Cl^-
Sulphate anion	+	Very poor		96.06	$S\bar{O}_4^{\bar{}}$
Acetate anion	+	(Not given)		59.04	$CH_3C\bar{O}\bar{O}$
Bicarbonate anion	±	(Not given)		61.02	$H\bar{C}O_3$
Carbonate anion	±	Fair		60.01	$C\bar{O}_3^{\bar{}}$
Carbon dioxide	±	(Not given)		44.01	CO_2
Oxalate anion		Fair		89.02	$(C\bar{O}\bar{O})_2^{\bar{}}$
Tartrate anion		Very good		149.08	$(C_2H_2O_3)_2^{\bar{}}$
Citrate anion		Excellent		189.09	$C_6H_5\bar{O}_7^{\bar{}}$

ill advised to tack on a treatise for slime prevention. Suffice it to state that quantities of rosin size on which a mill can get by in cold weather, fail when warm weather comes—unless the mill is kept as free from bacteria and molds in the warm weather as it is in the cold.

Failure of sizing in warm weather is manifest either in failure to size right from the start when the sheet is formed, or in fugitive sizing, which tests all right when the sheet is made, but which disappears, usually overnight, but sometimes after a week. Complete failure to size is seldom rectified by increasing the amount of regular rosin size. But as stated before, it can be overcome by the use of increased amounts of fortified size. Fugitive sizing can frequently be corrected by increasing the amount of regular rosin size, or by using some wax size.

An increase in the amount of rosin size used, invariably tends to promote foaming and even to increase slime formation, hence to accelerate bacterial growth. Therefore it is better to prevent the start of what can be a very vicious circle by increasing the use of slime killers in warm weather. This is preferable to allowing slime first to form, and then increasing the amount of rosin size employed, sometimes to no avail.

As stated before, the 0.015 to 0.020% alum concentration which is essential for good sizing will, according to Rudolfs and Nemerow (*35*) be effective in reducing slime growth.

SUMMARY AND CONCLUSIONS

1. Alum plays a quintuple role in paper sizing: (a) Alum precipitates the rosin. (b) Alum raises the contact angle against water of the rosin precipitate. Alone, rosin has a static contact angle against water of only approximately 60°. Aluminum resinate has an angle of approximately 100°. According to Ekwall and Bruun (*18*) the *monoresinate* of aluminum has the highest contact angle and should be the one to form in paper sizing. (c) Alum forms a film with rosin which according to Langmuir (*22*) is a rigid, nonfugitive solid. (d) Alum binds both cellulose fiber and anionic rosin sizing material together through the coordinate valences of the aluminum ion. (e) Alum helps to inhibit the bacterial production of highly coordinated anions inimical to good sizing.

2. According to the contact angle theory of sizing, porous open stock such as blotting paper or filter paper should be the most difficult to size against liquids.

3. High contact angle is vital in the sizing of porous paper. Aluminum resinate and paraffin wax with static contact angles against water of 100° will size blotting paper against water. Calcium resinate and rosin without alum will not; the contact angles of these last are too low, 70 and 60°, respectively.

4. By impregnation, it has been found that even porous blotting paper may be sized against water with as little as 0.5% rosin set on the fiber by alum.

5. There is a discrepancy between the minimum per cent rosin needed for sizing by impregnation of preformed paper stock and the amount of rosin needed for sizing in the mill, where aqueous rosin dispersions are precipitated with alum. This discrepancy emphasizes the problem of securing and keeping an effective size precipitate on the fiber during stock preparation and sheet formation.

6. Precipitation of rosin by alum at lower-than-beater stock consistencies offers advantages and promotes sizing efficiencies. It is felt that precipitation at 1 to 2% stock consistencies should offer special advantages, for there the rosin floc is not too coarse, and yet the fiber-to-floc distances are not too great for retention by coordination.

7. Sizing studies over the poor-to-good sizing range may be made very easily by using stock at one consistency, as 0.4% fiber, for both precipitating the size and forming the handsheet in the Noble and Wood mold; making a heavy handsheet, 7 grams, and testing the dried sheet for sizing by TAPPI Standard T 441 m-45.

8. Those alum salts which have anions of low coordinating affinity, namely the nitrates, chlorides, sulphates, and acetates, will set rosin size satisfactorily on the fibers and thus raise the contact angle of the fibers to the point where the stock is sized.

9. In the case of aluminum salts with anions of high coordinating affinity, such as citrates, oxalates, and tartrates, however, the anions highly coordinated to aluminum cannot be replaced on the aluminum by cellulose and rosin size. Therefore sizing is blocked and prevented when aluminum salts with such anions are used, or even when such anions are present in the sizing system. These facts are in accord with the coordination theory propounded before TAPPI in 1935 by A. W. Thomas (*40*).

10. Carbon dioxide or the carbonates are more highly coordinated to aluminum than the inorganic anions, and not so highly coordinated as the complex organic anions. This has been brought out when it was found that while low concentrations of carbon dioxide or carbonates can be tolerated, higher concentrations of these anions will block or prevent sizing.

11. The concentration of alum in the stock suspension on wire or in cylinder vats is probably more important for paper sizing than the alum/rosin ratio so long considered vital. Alum concentration at the point of sheet formation in the mill should be close to 0.015–.02% $Al_2(SO_4)_3 \cdot 14H_2O$. This is confirmed by the results of other workers.

12. At concentrations of alum salts under the equivalent of 0.015–.02% $Al_2(SO_4)_3 \cdot 14H_2O$, adjusting the pH of the system with acid to 4.3 to 4.5 improves the sizing.

13. The qualitative test for alum described by Morgan (*27*) can be adapted into an effective roughly quantitative alum control test, using 5% hematein in alcohol as an indicator for alum.

14. The structure of cellulose indicates it has sufficient available OH linkages for coordination to aluminum. But the abietic acid or rosin structure with its one OH group per molecule, does not. From the coordination viewpoint, therefore, it is not surprising to find that fortified rosin size, with its increased number of OH groups, is reported to have greater sizing efficiency than ordinary rosin size.

15. Hot weather sizing difficulties are given a logical explanation by considering that bacterial action in the mill may by its very nature produce highly coordinated organic anions such as the citrates or oxalates, which will destroy sizing if present in any amount. Paper and pulp mill cleanliness is therefore important for good sizing as well as for slime control.

16. It has usually been considered that some pulps

are easier to size than others, because the easier-to-size pulps contain more naturally water-resistant resins. But from this work it becomes apparent that some pulps may be easier to size, just because they do *not* contain highly coordinated organic anions, such as the oxalaic or lignosulphonic acid which may originate in the pulping process.

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Effects of Speed of Test on Bending Strength of Insulation Fiberboard

WAYNE C. LEWIS

Representative 1/2-in.-thick interior-type and 3/4-in. sheathing-type structural insulation boards from three manufacturers were each tested under four different rates of loading where the time of test from the start of load application to failure of specimen ranged from about 5 to 90 sec. The results from the 240 tests included in this study aided in establishing a recommended speed of test for a suggested TAPPI quality-control test procedure (T 1003 sm-53) for structural insulation boards. The recommendation is that the specimen shall be loaded at a uniform rate of separation of the heads of the testing machine such that the specimen will be failed in 60 ± 15 sec. The tests indicated, that the bending-strength (modulus of rupture) values decreased about 6% for 1/2-in.-thick board and about 10% for 3/4-in. for each tenfold increase in the duration of test.

Wayne C. Lewis, Engineer, Forest Products Laboratory, maintained at Madison, Wis., in cooperation with the University of Wisconsin, Forest Service, U. S. Department of Agriculture.

This project was sponsored by the TAPPI Structural Fibrous Materials Committee and was supported by TAPPI Research Grant No. 32. The tests summarized in this report are the result of an assignment to a subcommittee of the Structural Fibrous Materials Committee of TAPPI on "Transverse and Deflection Testing," consisting of John F. Campbell, Flintkote Co., chairman, E. A. Lauring, Minnesota and Ontario Paper Co., R. H. Neisel, Johns-Manville Corp., and the author.

The increased use of insulation fiberboards as structural materials and the need for uniformity in manufacture, as well as for assuring minimum strength for specification purposes, has increased the importance of the flexure test as a quality-control tool. The need for a uniform test procedure that all manufacturers could use for maintaining quality control in manufacture is recognized. There are three test procedures that could be used for flexure testing of insulation board. American Society for Testing Materials has a procedure in "Tentative Methods of Test for Evaluating Building Fiber Board," D 1037 –52T, which is intended for engineering evaluations of the mechanical properties of all of the building fiberboards, of which structural insulation board is only one. That test method requires refinements in procedural technique that are not usually warranted in a quality-control procedure. Federal Specification LLL-F-321b, "Fiberboard, Insulating," and ASTM Standard C 209–48, "Methods of Testing Structural Insulating Board Made from Vegetable Fibers," are the other two. These latter two

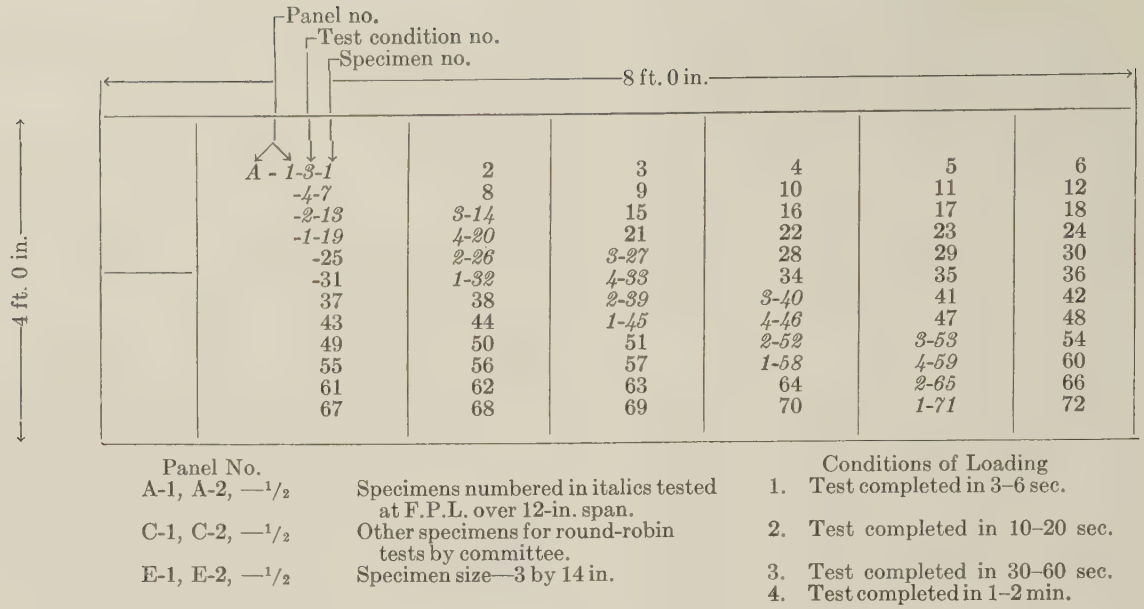

Fig. 1. Layout of specimens for 1/2-in. insulation board

are alike in all respects except for speed of test. The Federal specification requires that the rate of head travel of the testing machine shall be 12 ± 2 in. per min., while the ASTM procedure requires a rate of head travel of 6±2 in. per min. Both the 6- and the 12-in. rate of head travel are considered to be too fast. At a speed of 6 in. per min. failure usually will occur in 3/4-in. boards in less than 10 sec., while at 12 in. per min., failure occurs in less than 5 sec. Erroneously high maximum loads may be observed because of inertia effects in the weighing systems of testing machines at these high rates of loading.

Consequently, the Structural Fiber Materials Committee of TAPPI set up a task group to study the different available test procedures and to try to develop a procedure that would satisfy the needs of the industry for quality control of insulation board. Such a procedure ideally should satisfy the following requirements:

1. The test should be as simple as possible and require a minimum of expensive equipment.
2. A single span and specimen size would be preferable, if possible, for all common thicknesses of insulation board ranging from 3/8 to 1 in.
3. The test should not be too time-consuming so that a sufficient number of tests could be made to keep the time interval between manufacture and evaluation to a practical minimum.
4. The procedure should result in uniform and accurate results that are comparable among different investigators.
5. The test procedure should be adaptable to any testing machine having required speeds for loading, and sufficiently accurate load-measuring equipment.

A TAPPI Research Grant was made to the Forest Products Laboratory to make a series of flexure tests at different rates of loading on representative insulation boards to obtain basic information that could be used for background for the development of a quality-control test procedure. This report presents the results of those tests.

Three representative nominal 3/4-in.-thick sheathing-type boards and three representative 1/2-in.-thick interior-type boards were included in the test program. Two sheets of each thickness, each 4 by 8 ft. in area, were furnished by the Johns-Manville Corp., the Flintkote Co., and the Celotex Corp.

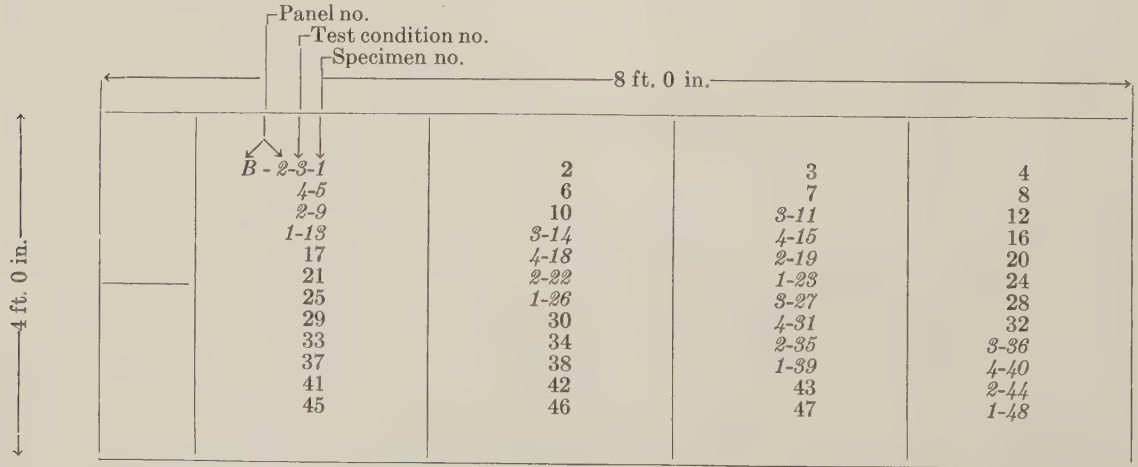

Fig. 2. Layout of specimens for 3/4-in. insulation board

The plan for the tests required that the tests of each material be divided into four groups so that an equal number of specimens from each board could be tested under each of the following loading conditions.

1. Test completed in 3 to 6 sec.
2. Test completed in 10 to 20 sec.
3. Test completed in 30 to 60 sec.
4. Test completed in 1 to 2 min.

Specimens were sawn from each board as shown diagrammatically in Figs. 1 and 2. Figure 1 shows the cutting diagram for the 1/2-in.-thick board, and Fig. 2, the diagram for the nominal 3/4-in.-thick board. The 1/2-in.-thick specimens were each 3 by 14 in., and the 3/4-in.-thick specimens were each 3 by 20 in. As shown in Figs. 1 and 2, specimens were not prepared from near the edge or ends of the panels to minimize any variations in test results that could be attributed to material near the edge having greater or less strength than that in the other parts of the panel.

Five specimens for each loading condition were prepared from each panel. The specimens for test at the different rates of loading are shown in italics on Figs. 1 and 2. Extra specimens were set aside for possible additional tests.

METHOD OF TEST

All specimens were conditioned to equilibrium moisture content at 75°F. and 50% R.H. before test and were tested at the prevailing laboratory condition before any measurable change in moisture content could occur. All tests were made in the same universal-type hydraulic testing machine. The testing machine was equipped with an air-cell load-measuring device so that the loads on the specimens could be accurately measured to the nearest 0.1 lb. Load-deflection curves were obtained from all tests, except those tested at the fastest rates of loading, so that values of modulus of elasticity could be computed. Spans were 12 in. for the 1/2-in. board and 18 in. for the 3/4-in. board.

The radius of the rounded supports and loading head was 3/8 in. All specimens were tested so that the same face was loaded in all tests. The loaded face was the numbered face, and for the interior-type boards it was the finished face. For the tests in this series the loading head of the testing machine was started in motion a fraction of an inch above the specimen to assure that the rate of head travel was uniform from the start to the end of the test.

Extra specimens were used for each condition of loading to determine the rate of head travel that produced failure in the prescribed time. Rates of head travel were selected so that failure occurred at about the half-way point in the allotted time. Thus in a test where failure was to occur in 10 to 20 sec. the rate of head travel was selected so that failure occurred in approximately 15 sec. All specimens were loaded at a uniform rate of head travel for the entire duration of test.

A summary of the results of the 240 tests is presented in Table. I Average values for each test condition are presented for time of test, modulus of elasticity, de-

Table I. Summary of Flexure-Test Results of Structural Insulation Boards Made at Different Speeds of Test[a]

Time for test, (1) sec.	*Test speed, (2) in./min.*	*Modulus of elasticity, (3) in.*	*Deflection at maximum load,[b] (4) in.*	*Maximum loads*			*Modulus of rupture*		
				Average,[b] (5) lb.	*Individual maximum (6) lb.*	*Individual minimum, (7) lb.*	*Average,[b] (8) p.s.i.*	*Individual maximum; (9) p.s.i.*	*Individual minimum, (10) p.s.i.*
			Tests of 1/2-In. Insulation Board A						
4	11.00	...	0.79	19.2	21.8	17.0	370	396	348
16	2.10	36,100	0.61	18.5	20.6	16.8	349	375	329
45	0.80	40,000	0.59	18.3	20.6	17.0	345	366	317
90	0.45	40,000	0.60	18.4	20.3	17.1	343	364	309
			Tests of 1/2-In. Insulation Board C						
3	11.00	...	0.55	20.9	22.5	20.1	451	483	432
15	2.10	49,400	0.52	20.8	21.9	19.3	448	475	421
45	0.70	53,900	0.51	20.0	20.7	19.1	429	444	414
88	0.35	53,900	0.50	19.7	20.6	18.7	426	446	411
			Tests of 1/2-In. Insulation Board E						
3	11.00	...	0.57	27.8	28.7	27.0	630	652	614
14	2.10	...	0.50	26.4	28.0	24.9	595	624	567
47	0.70	86,600	0.47	25.8	27.6	22.9	586	623	530
87	0.35	86,600	0.47	25.4	26.2	24.3	575	599	540
			Tests of 3/4-In. Insulation Board B						
5	11.00	...	0.94	33.2	34.2	31.6	427	443	394
18	2.80	51,700	0.82	32.0	33.4	30.8	414	429	399
50	1.00	53,100	0.81	31.4	33.0	29.3	398	410	392
84	0.55	55,000	0.82	30.3	31.6	28.8	390	406	370
			Tests of 3/4-In. Insulation Board D						
4	11.00	...	0.63	33.0	34.2	31.3	443	464	411
14	2.80	60,000	0.66	31.5	34.2	28.7	424	468	382
44	1.00	59,700	0.63	29.6	32.5	27.4	401	449	379
78	0.55	59,900	0.64	29.4	31.3	26.9	395	424	374
			Tests of 3/4-In. Insulation Board F						
4	11.00	...	0.67	42.2	44.5	40.0	577	604	551
13	2.80	...	0.62	38.3	39.8	36.5	531	550	516
47	0.80	88,000	0.57	36.0	38.6	33.7	500	529	474
82	0 50	90,500	0.58	35.8	36.5	35.0	494	504	481

[a] Specimens were nominally 3 in. wide; 1/2-in. specimens were tested under center loading of a 12-in. span, and 3/4-in. specimens were similarly loaded on an 18-in. span.
[b] Each value is the average of 10 tests.

flection at maximum load, maximum load, and modulus of rupture in columns 1,3,4,5, and 8, respectively. The maximum and minimum values for maximum load and modulus of rupture from the individual tests for each condition of loading are listed in columns 6, 7, 9, and 10.

Table II. Percentage Increases of Modulus of Rupture Based on Control Values at Slowest Testing Speeds in Series

Board	Testing speed, in./min.	Testing time, sec.	Modulus of rupture	
			P.s.i.	Per cent of control
A	11.00	4	370	107.9
	2.10	16	349	101.8
	0.80	45	345	100.6
	0.45	90	343	100
B	11.00	5	427	109.5
	2.80	18	414	106.2
	1.00	50	398	102.1
	0.55	84	390	100
C	11.00	3	451	105.9
	2.10	15	448	105.2
	0.70	45	429	100.7
	0.35	88	426	100
D	11.00	4	443	112.2
	2.80	14	424	107.4
	1.00	44	401	101.5
	0.55	78	395	100
E	11.00	3	630	109.6
	2.10	14	595	103.5
	0.70	47	586	101.9
	0.35	87	575	100
F	11.00	4	577	116.8
	2.80	13	531	107.5
	0.80	47	500	101.2
	0.50	82	494	100

Comparisions of the individual maximum and minimum values for maximum load and modulus of rupture show that in general the spread between high and low values from a group of 10 specimens decreased as the speed of loading decreased and the duration of load consequently increased. This indicates that the test results apparently are more uniform at the slower than at the faster rates of loading. That this is so, coupled with the fact that testing machines with mechanical or other weighing systems having appreciable mass, may give erroneously high maximum values at fast rates of loading, supports the contention that the slower rates of loading are preferable for quality-control tests of structural insulation board.

The practical aspects of a quality-control test were considered. It was the consensus that a duration of test of 1 min. was not unreasonable when the time and manpower available for testing in most insulation-board mills were considered. A comparison of the differences in values of modulus of elasticity, deflection at maximum load, and modulus of rupture between tests completed in about $^3/_4$ of a min. and those from the same board completed in about $1^1/_2$ min. indicated that differences were so small that for practical purposes they could be ignored. Consequently, it was recommended that the T 1003 sm-53 method have a requirement that for quality-control tests of insulation board the specimens shall be loaded at a uniform rate so that the maximum load will occur in 60 ± 15 sec.

A test with a duration of 60 sec. will allow sufficient load-deflection data to be obtained, when desired, to calculate the modulus of elasticity. Experience with the testing reported herein indicated that it was not difficult to determine the rate of head travel that would produce failure within the specified time limit for any type, thickness, or kind of insulation board. Two, or at the most three test runs at different speeds will indicate the desired speed for a given class of board.

It was evident from comparing the values of modulus of rupture obtained from the tests at the different rates of loading that as the duration of test increased, values of modulus of rupture decreased. This is reasonable and indicates that insulation board varies in ultimate strength with the rate of load application, as do other materials. The data were compared and plotted with the values of modulus of rupture as ordinates and the logarithms of the time to maximum load as abscissas. Because the strengths of the different boards were not the same, values for different rates of loading were presented as percentages of the strength at the slowest rate of loading for the same board. These values are tabulated in Table II. A similar investigation for strength of wood (*1*) indicated that when such a plot was used, the modulus of rupture varied approximately linearly with the logarithm of time to maximum load. Straight lines were located by inspection and drawn to fit the data from the tests of insulation board. These data are not conclusive, but they indicate that, for the range of testing speeds included in this study, the strength of $^3/_4$-in. board decreases about 10% for an increase of 10 times in the time of test. The corresponding decrease in strength of $^1/_2$-in. board for a tenfold increase in testing time is indicated to be about 6 %.

The indicated difference in strength between a test requiring 45 sec. to complete and one requiring 75 sec. to complete (60 ± 15 sec.) is about 2.2 and 1.3 % for the $^3/_4$ and $^1/_2$-in. boards, respectively. These differences are too small to be considered important. They support the range in testing time recommended for the quality-control test procedure.

CONCLUSIONS

Tests of the six typical interior and sheathing-grade structural insulation boards to provide background data for the preparation of a recommended procedure for making quality-control flexure tests indicate the following:

1. The values of maximum load and modulus of rupture are more uniform at slow rates of loading than at faster ones.
2. A test requiring $^3/_4$ of a min. or more to produce failure is slow enough so that sufficient load-deflection data can be obtained when desired to obtain a reasonable estimate of the modulus of elasticity of the material.
3. Strength of insulation board decreases as the time of testing increases. For the range of times to maximum bending strength included in this test series (5 to 90 sec.) the indicated decrease in modulus of rupture was about 10% for $^3/_4$-in. board and 6% for $^1/_2$-in. board for each tenfold increase in time of test.

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A Thermal Compression Evaporator for Spent Sulphite Liquor

D. CRAIG, H. ELGEE, and J. K. RUSSELL

A thermal compression evaporator for spent sulphite liquor consists essentially of a stainless steel long tube vertical evaporator body used in conjunction with a steam driven turbo compressor. Design capacity is 30,000 lb. water evaporation per hr. Operating data show that at this rate an evaporation ratio of 16.7 lb. water evaporated per pound of steam f & a 212°F. is obtained. Scaling is satisfactorily controlled by daily cleaning with recovered distillate from the evaporation.

THE evaporation of spent sulphite liquor presents several problems. In the first place, because of large amounts of water which must be evaporated and the relatively low value of the concentrate either as fuel or salable products, evaporating costs must be kept to a minimum. In the second place, scaling of the evaporator heat transfer surfaces is severe, largely on account of the calcium sulphate and calcium sulphite content which, because of their low and inverted solubility, are readily deposited. High wall temperatures tend to promote the conversion of the deposited dihydrate ($CaSO_4 \cdot 2H_2O$) to the hemihydrate ($CaSO_4 \cdot {}^1/_2H_2O$) and to the anhydrite ($CaSO_4$). These latter tend to form a glassy insoluble scale and for this reason it is desirable to keep the temperatures in the evaporator as low as possible. A further reason for operating at as low temperatures as possible is found in the heat sensitivity of the lignosulphonic acids which tend to undergo decomposition and/or polymerization if exposed to temperatures appreciably higher than the boiling point of water.

A number of multiple-effect evaporators are in service in Sweden, Norway, Germany, and the United States. They have the disadvantage that in order to accommodate sufficient effects to give acceptable heat economy, three or preferably four are required, and they must work over a considerable temperature range with consequent high temperatures in one or more of the effects. One installation at least operates with all effects except one under reduced pressure in order to reduce scaling difficulties. A number of others, principally in Sweden, employ an evaporator design whereby the liquor and steam passages in the heat exchanger are interchanged at short periods in order to dissolve the scale in the condensed distillate. These latter are said to give satisfactory performance but are used chiefly for the production of liquor for subsequent burning for its fuel value so that any alteration in the properties of liquor is of no importance.

Vapor compression evaporators have recently come into fairly extensive use in services where heat economy and compact installation are of first importance as for instance in the preparation of potable water on submarines and other craft and similar services (*1*). Insofar as the evaporation of sulphite liquor is concerned they have the advantage of simplicity of operation, low temperature differential, and low level of temperature in the evaporator without the introduction of reduced pressure. This will diminish scaling difficulties and make unlikely any appreciable alteration in chemical or physical properties of the product during evaporation. The most important advantage lies in the extremely high heat economy with which they operate that may, under favorable conditions of temperature differential give results equivalent to those which would be obtained with a 15-effect evaporator. Sulphite liquor evaporation is a particularly promising application for the vapor compression cycle since the small elevation of boiling point, not more than 2°F., permits operation with a low temperature differential with consequent high potential efficiency.

The vapor compression cycle, as applied to evaporation, consists essentially in recovery of the vapors from the boiling liquid and compression of the vapors in a suitable compressor to a pressure corresponding to a temperature sufficiently above the boiling point of the liquid to obtain a satisfactory rate of heat transfer in the evaporator heat exchanger. The compressed vapors are then introduced to the evaporator heat exchanger where the latent heat is transferred to the boiling liquid. The sensible heat in the condensed distillate may be used for feed preheating.

The cycle permits the introduction of all heat required, apart from small radiation loss as may be made up by the addition of direct heat, as mechanical energy. The addition of the small amount of energy required to raise the temperature of the vapor above the liquid boiling point permits the recovery of the much larger amounts of energy present as latent heat. It may be considered, thermodynamically, as a heat engine in reverse, as are refrigerating machines and other types of heat pumps. It is the simplest form of heat pump since the material being heated is used as heat transfer medium and the use of a throttling device is avoided.

PILOT PLANT

Preliminary discussion with the producers of equipment revealed that while there appeared to be no reason why the cycle could not be successfully applied to the evaporation of sulphite liquors, no installations for this purpose had been made on this continent, nor installations of the size required been made by any purpose. It was felt consequently that it would be advisable to acquire some pilot plant experience before proceeding with the design of a full scale evaporator. A pilot plant with an evaporating capacity of about

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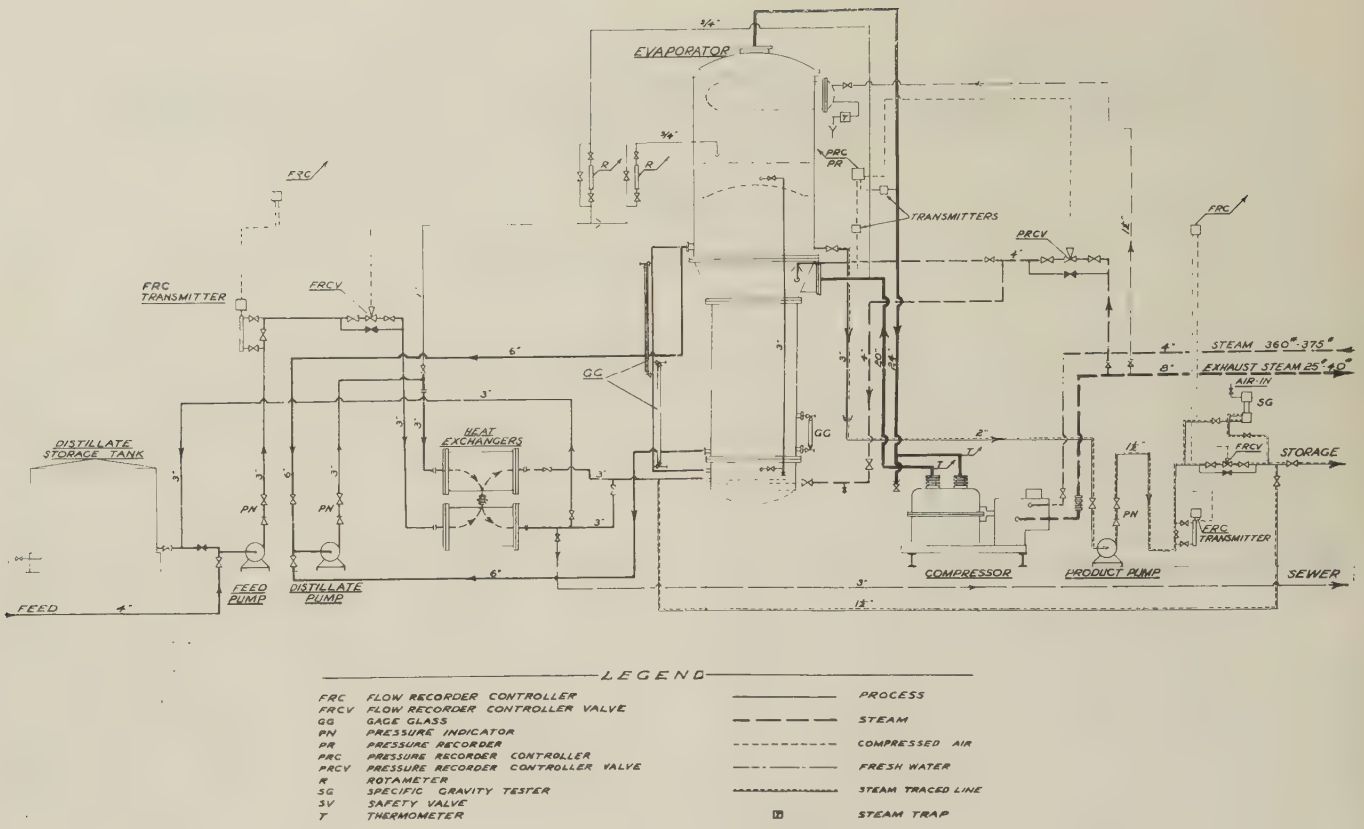

Fig. 1. Vapor compression evaporating plant flow diagram

400 lb. per hr. was designed and built by E. B. Badger & Sons (now Badger Process Div. of Stone & Webster Engineering Corp.). The pilot plant was operated intermittently over a period of a year. The installation and operation of the pilot plant have already been reported (*2*).

The evaporator consists essentially of a condenser-evaporator and a centrifugal blower. The vapors from the boiling liquid in the evaporator are withdrawn and introduced to the blower where the pressure is increased from 0.5 to 7.5 p.s.i.g. and the temperature from 216°F. to a level somewhat higher than the temperature of saturated vapor at the higher pressure. The temperature difference is due to the superheat produced in the compressor which is in turn a function of the compressor efficiency. The compressed vapors are then introduced into the condenser side of the condenser-evaporator where the latent heat is transferred to the boiling liquor in the tubes. Condensate at a temperature approximating that corresponding to the pressure in the condenser is removed from the base of the condenser and delivered to two preheater heat exchangers where its sensible heat is utilized in preheating the feed. Concentrated product is withdrawn from a take-off on the natural recirculation line. A flow diagram of the unit is shown in Fig. 1.

The evaporator proper is of the long tube rising film type with natural circulation. The tubes are 16 ft. long by $1^1/_4$ in. outside diameter, 1777 in number, to give a total heat exchange surface of 9300 sq. ft. They are set in 72-in. diameter tube sheets, the top being $1^1/_2$ and bottom 2 in. thick. The shell is $^3/_{16}$-in. stainless steel welded construction. The base of the shell, below the bottom tube sheet, is $^1/_4$-in. stainless steel with sufficient strength to support the total weight of the evaporator body which is carried on a mild steel skirt $^3/_8$ in. thick directly under the evaporator.

Pilot plant experience had indicated that difficulties might be encountered with excessive foaming and carryover of entrained liquor into the compressor. This would be undesirable partly because of danger of corrosion on the compressor impellers if the dew point should be reached and partly because of lowered efficiency and possible abrasive action on the impellers and labyrinth seals if these should become coated with dried material. For this reason special precautions were being taken to prevent any carryover of liquid.

The vapor separation unit, located directly above the tube bundle, and secured by flanged connections to the evaporator section, is 14 ft. over-all height by 102 in. outside diameter and is constructed of $^3/_{16}$-in. stainless steel sheet. To ensure complete removal of both foam and entrained droplets, a series of entrainment devices was installed. These consist of baffle plates followed by a bubble cap tray.

To ensure that the vapor, as delivered to the blower, is safely above the dew point a superheater is installed in the top of the vapor separation space. The superheater is a finned tube heat exchanger with 660 sq. ft. of surface. It is supplied with steam at 30 p.s.i.g. and is designed to increase the vapor temperature by about 10°F. It is now operating to give 6 to 8°F. superheat.

The compressor is a three-stage centrifugal blower driven by a mechanical drive back pressure steam turbine at 5100 r.p.m. The compressor is designed to operate at an inlet pressure of 0.5 p.s.i.g. with a capacity at inlet of 14,500 c.f.m. Discharge pressure is 7.0 to 8 p.s.i.g., and temperature at the outlet, which is dependent on the internal efficiency of the blower and the pressure, varies between 300 and 305°F. The de-

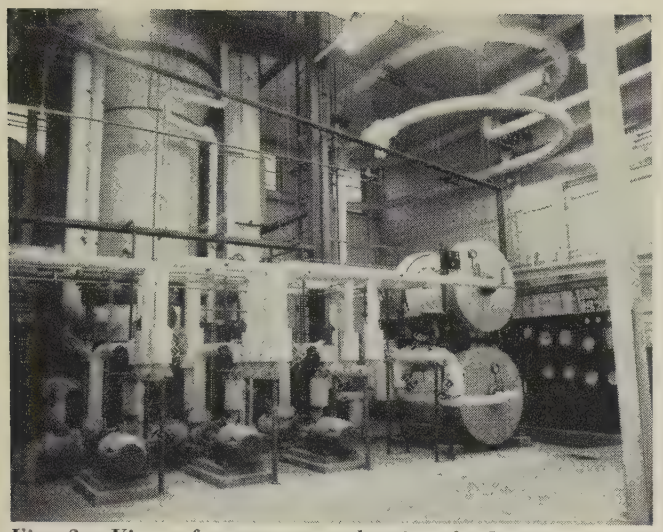

Fig. 2. View of evaporator showing feed pumps, heat exchangers and panel board

signed efficiency of the compressor is 68.5% and has been found to be 69 to 70% under actual operating conditions.

The rotating element consists of three shrouded-type impellers keyed to the impeller shaft, and the impellers are of welded construction throughout. The stationary element consists of a cast iron casing split on a horizontal center line and is fitted with cast iron diaphragms which serve as partitions between the stages and as guide vanes for the delivery of vapors to succeeding stages. Labyrinth seals are provided between the stages both at the shaft and at the periphery of the impellers. Inlet and outlet ports are cast integrally in the upper half of the blower casing. The entire blower casing is steam traced in order to keep the equipment above the dew point during shutdown periods and so avoid condensation of the extremely corrosive distillate.

The prime mover is a single-stage, mechanical drive back pressure steam turbine designed to operate at steam inlet pressure of 360 p.s.i.g. and total temperature of 550°F. with an exhaust of 40 p.s.i.g. Rated power is 488 hp. at 5100 r.p.m. The turbine is direct coupled to the compressor.

The compressed vapor on leaving the compressor is introduced into the condenser side of the evaporator where, giving up its latent heat to the boiling liquor, it is condensed at the temperature corresponding to the pressure in the condenser. The condensed distillate is conveyed through a distillate discharge pump to two heat exchangers where its sensible heat is utilized for preheating the incoming feed liquors. The heat exchangers are of spiral type with 800 sq. ft. heat exchange surface in each. They are connected in series and additional heat exchange capacity is provided in order to accommodate additional flows of distillate during the descaling periods as outlined below. Photographs giving two views of the installed unit are shown in Figs. 2 and 3.

The principal variables to be controlled are the solids content of the product, the rate of weak liquor feed, the level in the evaporator, and the suction pressure to the blower. It is apparent that the first three variables are inter-related and some consideration was originally given to an automatic control on the product solids content acting through a control valve on the product draw-off. This would act in conjunction with a level controller on the evaporator which would act on a control valve on the weak liquor feed. This was abandoned partly because the hold-up time in the evaporator would make it difficult to obtain satisfactory control and partly because an adequate method of measuring the solids in the product did not appear to be available at a reasonable cost. It was also felt that some operating experience should be obtained before an attempt was made to place the unit on completely automatic operation.

Consequently manually operated flow controllers were installed on both the raw liquor feed and product draw-off with a specific gravity indicator on the product draw-off in order to make certain that the product is kept on specification. A high and low level alarm of the electric contact type is also installed on the evaporator.

The flow controllers are of variable area type; that on the feed having a capacity of 30 to 270 i.g.p.m. Both are air operated with automatic reset and 200% proportional band and act through V port control valves. The specific gravity indicator is of a simple hydrometer type set in a well in a by-pass on the product line which is under a constant air pressure in order to prevent submergence of the hydrometer. A flow indicator of orifice rotameter type is installed on the distillate take-off line in order to provide a convenient check on the actual rate of evaporation at all times. This acts through a transmitter with the indicating instrument located on the panel board.

Small amounts of auxiliary heat are needed to offset heat losses through radiation and through the purge of

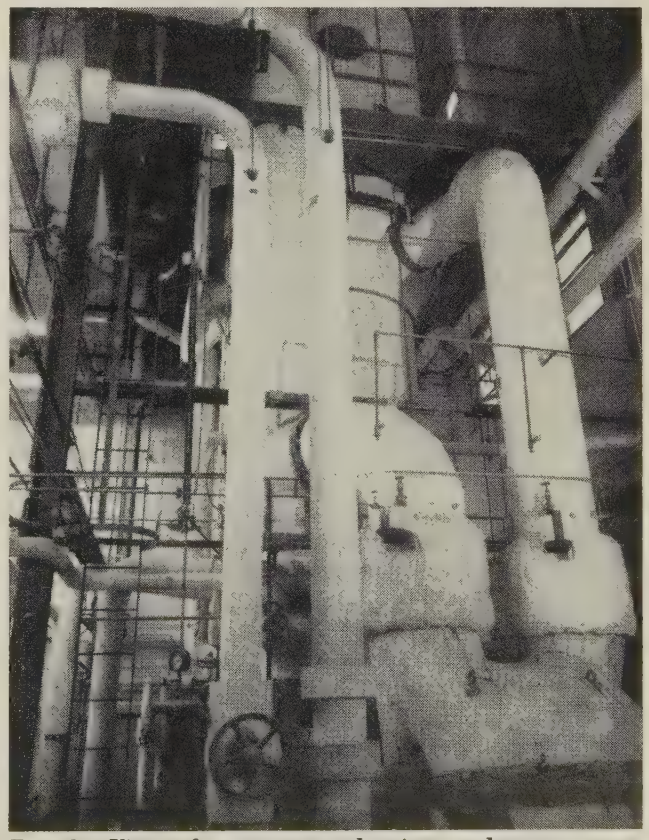

Fig. 3. View of evaporator showing turbo-compressor and evaporator body

noncondensables from the steam chest. Provision was made to supply this heat as low pressure steam directly to the liquor at the base of the evaporator and indirectly as additional steam to the steam chest. A condition of unbalance in the heat supply is indicated by a drop in pressure at the compressor suction, and the addition of auxiliary heat is controlled by a pressure controller located at this point. The controller is a differential pressure instrument acting against atmospheric pressure to maintain 0.5 p.s.i.g. in the vaporline. The compressor discharge pressure as well as the suction pressure is recorded on the same instrument. It has been found in practice that the additional heat supplied to the system through the inefficiency of the blower, which appears as superheat in the compressed vapor, is more than enough to make up the radiation and other losses and that consequently the purge is used to vent enough heat to keep the system in balance. The auxiliary heat is consequently used to offset the excess heat lost at the vent. It is necessary to operate in this manner in order to obtain satisfactory control of the blower suction pressure but it would now appear that satisfactory control might be obtained through an air controlled valve installed on the vent line. The valve would be operated with the same air supply as that to the auxiliary steam valve but would be opposite in action, i.e., would be air to close while the steam valve would be air to open. It is planned to have this valve installed in the near future.

Other instruments include recording thermometers on the compressor suction and discharge, flow indicators of variable area type on distillate to the bubble cap tray in the vapor separation unit, and to the desuperheater on the compressor discharge as well as manometers on compressor suction and discharge.

Materials of Construction

Raw sulphite liquor is very corrosive, and experience has indicated that it may be handled satisfactorily only in stainless steel. Corrosion test racks were installed in the pilot plant and these indicated that following exposure to high temperatures type 304 stainless would be subject to severe corrosion while extra low carbon type 316 showed only slight attack. Test rack tie rods which were type 304 not sensitized showed no attack.

Serious consideration was given to the use of type 304 in the tubes and tube sheets since these would not be subjected to high temperatures involved in welding. Subsequent examination of the pilot plant tubes and tube sheets, which were type 304, showed some pitting and it was felt that it would be advisable to use type 316 for this service. Consequently tubes and tube sheets were constructed of type 316 with 0.07% maximum carbon and all welded parts of the evaporator body were made from type 316 with 0.03% maximum carbon. The spiral heat exchangers which would be difficult to repair in the event of a failure were also made of extra low carbon 316 while piping and valves which are more readily accessible were made of standard (0.07% maximum carbon) type 316.

The compressor shell is cast iron and the rotors are chrome steel. Some consideration was given to the possibility of corrosion on the rotors but it was felt that with the intake safely above the dew point no difficulty should be encountered. The compressor has, however, been designed with three stages to operate at 5100 r.p.m. instead of the customary two stages operating at about 6000 r.p.m. Under these conditions the present rotors may be replaced by stainless steel if that should be necessary. This precaution has proved to be unnecessary since no attack on the rotors has occurred.

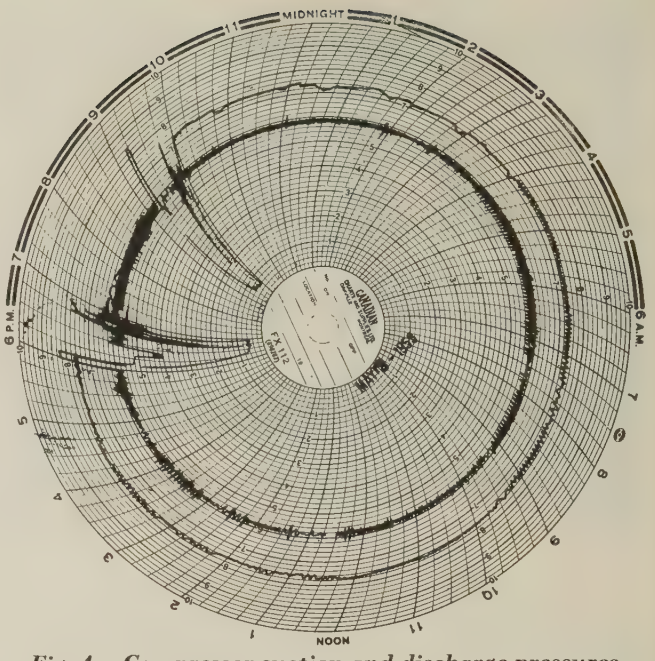

Fig. 4. Compressor suction and discharge pressures

In the whole system corrosion has been observed at only two points, both of these in the blower. At the first of these, severe corrosion occurred in carbon ring packing cases on the sealing glands on both the suction and discharge ends of the blower and was apparently due to condensation at these points. The reason for this is not clear but condensate in sealing steam supplied to the glands may have been a factor. This difficulty was overcome by replacing the inner section of the packing case with a stainless steel insert and no further corrosion has been observed here.

Severe corrosion has also occurred in the compressor casing in the first stage only. This was caused by the collection of condensate in this stage during shutdown periods due to inadequate drains in the compressor base. This situation has now been corrected and the corrosion reduced to minimum. It is expected that it will have been entirely eliminated by further steps taken to prevent condensation in the blower. It is believed that these difficulties would be entirely eliminated by the use of a bottom entry and discharge blower.

Operating Procedure

At start-up the evaporator is filled with dilute, or concentrated liquor, steam being admitted simultaneously at the base of the evaporator, the pumping rate being controlled so that the liquor in the evaporator is maintained at the boiling point at all times. In this way a severe water hammer in the sparger is avoided. The purge line at the base of the steam chest is kept open during this period, and the system purged until free of air and other noncondensable gases. The vapor separation unit and inlet vapor line are purged through

the compressor and this passage is sufficiently free to do so when the compressor is not operating. The non-condensables having been purged and the level in the evaporator adjusted, if necessary, the compressor is started and brought to operating speed. Steam flow to the superheater, distillate flow to the bubble cap tray and to the desuperheater are started and adjusted, and the auxiliary steam flow to the evaporator placed on automatic control. Raw liquor feed is adjusted to maintain the level in the evaporator and, when the specific gravity tests indicate that the required solids content has been reached, product draw-off is started and adjusted to maintain product quality; the raw liquid feed at the same time having been adjusted to compensate for the draw-off. When the unit is in operation, the only attention required is the making of minor adjustments of feed and product draw-off.

Scale Removal

As indicated above, spent sulphite liquor presents a severe scaling problem and although operation at reduced temperature produces a less intractable scale, severe scaling of the heat exchange surfaces is, nevertheless encountered. Satisfactory operation is obtained for about 20 hr. although a small steady decrease in the rate of heat transfer occurs over this period. It has been found that the scale can be removed through operation of the evaporator on recovered distillate provided a sufficient flow of distillate is used and adequate turbulence of the distillate in the tubes is promoted. This is achieved by increasing the flow to the evaporator during cleaning periods, from the regular feed rate of 65 to about 180 g.p.m. while simultaneously injecting low pressure steam at the base of the evaporator. Additional preheater heat exchange capacity was installed to accommodate this flow, and the feed pumps were equipped with two-speed motors in order to procure the increased flow during these periods. Four hours, which includes shutdown and start-up time, are required for the scale removal operation.

Operating Data

The steam economy of the unit was determined over an operating period of 14 hr., the period beginning after an interval of 2 hr. following start-up during which the operation was brought to a steady state. The rate of evaporation was determined by direct measurement of the change in level in the distillate tank and in some individual hourly rates, as noted, from readings of the distillate flowmeter. The tank was previously measured and a capacity of 2640 lb. per in. in height was established.

Steam consumptions were taken from integrator readings on a flowmeter on steam supplied to the turbine. Temperature and pressure readings were taken from recorder charts on the same instrument and have been averaged by inspection for each hour of operation. Enthalpy of the input steam has been derived from the steam tables for conditions corresponding to each hour of operation. Net heat consumption was calculated from these figures using an enthalpy of 1165 B.t.u. per lb. on the exhaust steam. This figure was derived from throttling colorimeter readings on the exhaust steam over an extended period and corresponds to a moisture content of about $^3/_4$ of 1% at these temperature and pressure conditions.

The average evaporation ratio (water evaporated per pound of steam) was obtained from the total of the hourly steam consumption as applied against the total water evaporated. The results are shown in Table I. A recorder chart showing suction and discharge pressures on the blower for the same period is shown in Fig. 4. The lower line gives the suction pressure in $^1/_{10}$ p.s.i.g. while the upper gives the discharge pressure in pounds per square inch.

It will be noted in Table I that the distillate output drops continuously over the period while at the same time there is a gradual increase in the discharge pressure on the blower. This is due to a gradual build-up of scale on the evaporator tubing but it will be seen that at the same time the steam flow drops so that the evaporation ratio is virtually unchanged. There are some variations in the evaporation ratio which are due to variations in the total steam flow to the turbine. The reasons for this are not clear but it is probably due to errors in reading.

An average evaporation ratio of 18.1 lb. per lb. of steam has been obtained. This does not include balancing steam on which it is impossible, on account of the metering conditions, to obtain a direct reading. The indications are that it will amount to about 150 lb. per hr. On this basis total heat consumption will be increased by 2100 lb. to give a total of 25,700 lb.

The evaporation ratio then becomes

Table I. Evaporation Rate and Steam Consumption

Weak liquor feed, 10.4% total solids; concentrated product, 48% total solids

Time	*Tank level, in.*	*Distillate, lbs./hr.*	*Steam to turbine*			*Heat consumption, lb./hr. f & a 212°F.*	*Evaporation ratio, lb./lb. steam*
			Flow, lb./hr.	*Pressure, p.s.i.g.*	*Temp., °F.*		
1:00 a.m.							
2:00	12	31,700	19,860	350	509	1,850	17.1
3:00	25	34,300	19,760	350	509	1,840	18.6
4:00	37	31,700	18,090	370	510	1,650	19.2
5:00	48	29,000	19,850	380	510	1,790	16.2
6:00	...	31,400[a]	18,940	370	510	1,730	18.1
7:00	...	30,800	18,690	360	510	1,730	17.8
8:00	...	30,800	18,800	350	505	1,700	18.1
9:00	...	31,400	17,810	390	512	1,600	19.6
10:00	...	31,400	18,030	390	512	1,630	19.3
11:00	...	31,400	19,060	380	512	1,720	18.3
12:00 n.	...	29,600	21,800	390	510	1,940	15.2
1:00 p.m.	...	29,000	14,390	390	510	1,280	22.6
2:00	...	27,800	17,880	390	510	1,590	17.5
3:00	162	27,200	16,740	380	510	1,510	18.0
Totals		427,500				23,560	18.1 Av.

[a] Distillation rate from 6:00 a.m. to 2:00 p.m. taken from distillate flowmeter readings.

$$\frac{427{,}500 \text{ lb. water}}{25{,}700 \text{ lb. steam}} = 16.7 \text{ lb./lb. steam}$$

This represents the economy during actual operating periods but does not take any account of the steam used during (unproductive) cleaning periods. The cleaning occupies about 2 hr. operation on distillate so that total steam consumption will be increased by about 10% and the net ratio becomes about 15.0 lb. per lb. steam. Actual steam consumption during the cleaning period on the day in question gives ratio of 14.8 lb. per lb.

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The Simultaneous Process Control of Two Tests

GEOFFREY BEALL and T. A. PASCOE

When some general character of a product is indicated by two tests, they should be considered simultaneously in control. An example is given to demonstrate the application of the statistical procedure.

When some general quality of a product is to be controlled it frequently happens that more than one test may be made with the idea that each decides, in some measure, the suitability of the product. A familiar example is the case where suitability of paper is judged by both tear and bursting strength tests. Many other such situations may be imagined, such as the case considered below, when both percentage of chips too small and percentage too large are considered simultaneously as an indication of control in the operation of chipping. It follows that it is insufficient if either lies within control limits since failure of the other may still make the product undesirable. This situation may perhaps be handled by setting up two control charts and demanding that both tests be in control. Both tests may, however, be in control but each so near its respective critical line that the conjunction of dubious quality indicates an unsuitable product. It is the intent herein to consider this problem of a simultaneous view of the case of two tests. In these cases, commonly, chance fluctuations in one test are correlated (positively or negatively) with chance fluctuations in the other. Thus, both tear and burst are related to the performance of paper and one may become greater as the other becomes less, particularly if beating is varied. If such correlation occurs the simultaneous consideration of the two tests is more profitable than when they are relatively near independence.

In case anyone should think us abstract let us illustrate the problem with a homely example. A teacher sets up certain limits which are considered critical in any school subject. Perhaps he says that a grade of 60% is failing. Now it is regarded as serious if a student approaches 60% in all subjects, even though he fails in none. Such a conjunction of miserable performance raises grave questions on the subsequent performance of the product— in this case a graduate. So should we concern ourselves with an unfavorable conjunction of tear and bursting strength, even though neither of them is unquestionably bad in itself?

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It should be understood in the following discussion that reference is made to the critical limits of a process in the Shewhart or statistical sense. That is to say, we inquire what are the limits of variation characteristic of a given process as it exists currently. It may easily be that these limits are greater than the consumer tolerance, which is unfortunate but is unavoidable if the machine and procedure remain unchanged. It also happens, not infrequently, that the statistical limits are more narrow than is necessary for consumer tolerance.

ILLUSTRATIVE EXPERIMENTAL RESULTS

The data chosen to illustrate the problem of simultaneous test happens to be one of chip size in the operations of the Nekoosa-Edwards Paper Co. as obtained by the second author (T. A. P.). These data were collected 10 years ago and are now only of historic interest apropos the operation of chipping. They serve, however, very conveniently for illustration of theory.

Successive lots of chips were taken from a spout delivering them to the chip bin at the Nekoosa plant. Thirty lots, each of some 5 or 6 kg. (as shown in part in Table I), were taken. Each lot was put through a mechanical analytical chip screen and a fraction was collected on each of four screens, together with a fifth fine residue. The analytical chip screen consisted of four trays, one above the other, at a slight slope, made of wire mesh which was smaller in the successive trays. Each tray led to a spout. The entire nest was contained in a frame subject to violent mechanical vibration. In operation, chips were placed on the uppermost tray; they passed down until they reached a tray from which they could pass only by the appropriate spout. For present purposes, the primary data from the analytical chip screen were simplified as in Table I by considering only the weight of those (called too large) retained by the first 1-in. screen and those (called too small) passing through the third $^1/_2$-in. mesh screen. Since the only importance of Table I is to give an idea of the experimental work, only the first 15 lots are shown. The same data, in percentage form, are shown in Table II, for all the 30 lots considered.

LIMITS FOR SIMULTANEOUS CONTROL

In the present case we might, as previously mentioned, set up limits for the control of percentage too small and percentage too large, independently. We

Table I. Grams of Chips per Sample by Classification of Small, Right, and Large, for First 15 Lots

Lot →	*1*	*2*	*3*	*4*	*5*
Small	1085	1380	1320	1715	1180
Right	2315	4205	2075	2090	3475
Large	915	480	555	845	490
Total	4315	6065	3950	4650	5145
Lot →	*6*	*7*	*8*	*9*	*10*
Small	1135	1275	1085	1690	975
Right	2915	2640	2895	2865	1970
Large	865	700	645	400	825
Total	4915	4615	4625	4955	3770
Lot →	*11*	*12*	*13*	*14*	*15*
Small	1135	1330	1165	1185	1035
Right	2685	3000	3510	2220	1790
Large	1035	275	555	915	815
Total	4855	4605	5230	4320	3640

should note that in the data of Table II the situation may be summarized as follows:

	Percentage small	*Percentage large*
Average	27.77	13.93
Standard deviation	5.64	6.14

If now we set 2-sigma limits we shall consider the process out of control whenever the percentage too small is 27.77 ± 2(5.64), that is, for the present practical purposes, whenever 40% or more are too small. Similarly we shall consider the process out of control whenever 27% or more are too large.

If, however, we wish to look at the process as a whole, we shall consider the percentages too small and too large simultaneously. To do this we may calculate a value (for the present data) of

$$K^* = 44.23 - 2.396x - 1.575y + 0.03671x^2 + 0.03099y^2 + 0.02561xy$$

* It would be undesirable here to go into detail of the theory and calculation involved in the various statements. These are simply the procedure becoming a bivariate normal surface, to which the present data substantially conform. The value

$$K = (x^2\sigma_y^2 + y^2\sigma_x^2 - 2rxy\ \sigma_x\sigma_y)/\sigma_x^2\sigma_y^2\ (1 - r^2)$$

where x and y are referred to their respective averages. If $e^{-K/2}$ is set at $P = 0.045,500,2$ (to get limits comparable with 2-sigma), $K = 6.180,077$. If it should be required to set up the control limits as in Tables III and V, one may plot the ellipse

$$y = \sigma_y\{rx \pm \sqrt{(r^2 - 1)\ (x^2 + 2\sigma_x^2 \ln P)}\}/x$$

in the present problem $r = -0.38$. A good reference on the bivariate surface is Tippett, L. H. C., 1952, "The Methods of Statistics" (ed. 4), Wiley, N. Y.

Table II. Percentage of Chips per Sample by Classification of Small and Large

Lot →	*1*	*2*	*3*	*4*	*5*
Small	25	23	33	37	23
Large	21	8	14	18	9
Lot →	*6*	*7*	*8*	*9*	*10*
Small	23	28	23	34	26
Large	18	15	14	8	22
Lot →	*11*	*12*	*13*	*14*	*15*
Small	24	29	22	28	29
Large	21	6	11	21	22
Lot →	*16*	*17*	*18*	*19*	*20*
Small	33	27	23	36	19
Large	14	13	23	3	20
Lot →	*21*	*22*	*23*	*24*	*25*
Small	23	30	23	37	29
Large	15	17	11	4	14
Lot →	*26*	*27*	*28*	*29*	*30*
Small	26	36	16	34	34
Large	10	3	14	5	19

where x is percentage too small and y is percentage too large and K is a constant related to the improbability of any given combination of percentages too small and too large. The value K has this force in the sense that $e^{-K/2}$ is the probability of the given combination. Let us not worry about the details of this algebraic question but consider Table III which shows the values of K for the various combinations of percentage too small and too large in the present case. Thus, when 40% are too small and 15% are too large K is 5.9 and the combination is comparatively improbable. The same value of $K = 5.9$ arises when 31% are too small and 26% are too large. We see accordingly that these two cases are equally improbable. On the other hand, when 28% are too small and 14% are too large, in that table $K = 0.0$ which, being the least possible value of K, shows that the combination is not improbable. This is reasonable since the values (28 and 14%) considered are the average small and large which are very probable values so long as the process stays in control. Let us now propose that we exclude, as beyond a reasonable control limit, all combinations of small and large that are extremely improbable. Let us specifically exclude all combinations at or beyond a value of $K = 6.2$. This value is chosen because then 0.045,500,2, say 0.05, of the cases are excluded. This level corresponds to the 2-sigma limit. In Table III, the values of K are not shown when they equal or exceed 6.2. Accordingly, we may say that for the present problem an observation is in control when it falls in that part of the field for which K values are shown and the process is out of control outside that part of the field.

If the present data were taken as a base study it would now be straightforward to set up a simultaneous control scheme to regulate mill operation in process. In order to maintain the present limits on fraction too small and large, it would be required to adjust the equipment or process when there should be significant sign of a departure from the present level, i.e., if any point fell beyond the 0.05 contour (the part of the field for which K is shown) in Table III as further lots of chips should be drawn from the chip spout. Such process control might be used to check setting or wear of the chipper during a shift, for example.

Table V provides an illustration of how the simultaneous control might be expected to work when the present operation of chipping should go out of control. In order to provide an illustration of how the simultaneous control for two tests might work out, suppose first that the simultaneous control limits had been set up, along the line of Table III. Suppose afterwards that the average percentage of chips too small should rise to 27.77 + 6=33.77 and the percentage of chips too large should rise to 13.93 + 6=19.93. Then a mill would obtain data like those of Table II except for a general increase in level of these unsatisfactory fractions by an amount of 6%. Such imaginary results have been obtained from Table II to give the data of Table IV. These data would be entered directly (as they arose) in the scheme of Table V which shows the simultaneous limits on the critical combinations of fractions too small and too large. The critical limit is indicated by a thick line which, starting at the top of the sheet runs down between 41 and 42% too small till it reaches 13% too large. At this point it jogs over to run down be-

Table III. Values of K for Percentage Too Small and Percentage Too Large of Chips

Large, %	Percentage too small: 14	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
0												5.9	5.5	5.9	5.6	5.4	5.2	5.2	5.2	5.2	5.4	5.6	5.9				
1										6.1	5.5	5.1	4.7	5.1	4.8	4.6	4.5	4.4	4.5	4.6	4.7	4.9	5.3	5.6	6.1		
2									5.9	5.3	4.8	4.3	3.9	4.3	4.1	3.9	3.8	3.8	3.8	3.9	4.1	4.4	4.7	5.1	5.6	5.8	
3									5.1	4.5	4.0	3.6	3.3	3.6	3.4	3.3	3.2	3.2	3.2	3.4	3.6	3.9	4.2	4.7	5.2	5.4	5.8
4								5.7	4.4	3.9	3.4	3.0	2.7	3.0	2.8	2.7	2.6	2.7	2.9	3.1	3.4	3.5	3.8	4.3	4.8	5.2	5.4
5							5.7	4.3	3.8	3.2	2.8	2.4	2.1	2.6	2.4	2.1	2.2	2.3	2.5	2.7	3.1	3.5	4.0	4.5	5.0	5.2	5.7
6							5.0	3.7	3.2	2.7	2.3	1.9	1.6	2.2	2.1	1.7	1.7	1.9	2.1	2.4	2.7	3.2	3.7	4.3	5.0	5.2	5.7
7						5.7	4.4	3.2	2.7	2.2	1.8	1.4	1.1	1.8	1.7	1.4	1.4	1.6	1.8	2.1	2.5	3.0	3.5	4.1	4.8	5.2	5.6
8						5.1	3.8	2.7	2.2	1.8	1.4	1.1	0.8	1.5	1.3	1.1	1.1	1.3	1.6	1.8	2.3	2.8	3.4	4.0	4.7	5.2	5.5
9					5.9	4.5	3.3	2.3	1.8	1.4	1.1	0.8	0.5	1.1	1.0	0.7	0.7	1.0	1.4	1.8	2.2	2.7	3.3	4.0	4.7	5.2	5.6
10					5.2	4.0	2.8	2.3	1.8	1.4	1.1	0.8	0.5	1.0	0.8	0.4	0.4	0.7	1.1	1.4	1.8	2.2	2.7	3.3	4.0	4.7	5.2
11					4.7	3.5	2.4	1.9	1.5	1.1	0.8	0.5	0.3	0.8	0.6	0.4	0.5	0.7	1.0	1.3	1.7	2.1	2.7	3.3	4.1	4.8	5.2
12					4.2	3.1	2.2	1.6	1.2	0.8	0.6	0.3	0.2	0.5	0.3	0.3	0.3	0.6	0.9	1.2	1.6	2.1	2.7	3.3	4.2	4.8	5.2
13					3.8	2.8	2.0	1.4	1.0	0.6	0.5	0.2	0.1	0.3	0.2	0.2	0.2	0.6	0.9	1.3	1.8	2.3	2.9	3.6	4.4	5.0	5.5
14					3.4	2.6	1.9	1.2	0.8	0.5	0.3	0.2	0.1	0.2	0.1	0.1	0.1	0.4	0.7	1.1	1.6	2.2	2.7	3.4	4.2	4.8	5.3
15					3.1	2.3	1.7	1.1	0.7	0.4	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.2	0.5	1.0	1.4	1.9	2.5	3.1	3.9	4.6	5.2
16					2.8	2.1	1.5	1.0	0.7	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.2	1.6	2.2	2.8	3.6	4.4	5.0
17					2.5	1.9	1.4	1.0	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.7	1.1	1.6	2.1	2.7	3.4	4.2	4.9
18					2.3	1.7	1.2	0.8	0.5	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.9	1.4	1.9	2.5	3.2	3.9	4.6
19					2.1	1.5	1.1	0.7	0.5	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.2	1.7	2.2	2.9	3.6	4.3
20					1.9	1.4	1.0	0.7	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.0	1.4	2.0	2.6	3.3	4.0
21					1.7	1.2	0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.2	1.7	2.3	3.0	3.7
22					1.5	1.0	0.7	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.0	1.5	2.1	2.8	3.5
23					1.4	0.9	0.6	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.4	0.8	1.3	1.9	2.6	3.3
24					1.2	0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	1.1	1.7	2.4	3.1
25					1.0	0.7	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.8	1.4	2.1	2.8
26					0.8	0.5	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	1.8	2.5
27					0.6	0.4	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	1.5	2.2
28					0.4	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	1.1	1.9
29					0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	1.5

tween 40 and 41% too small for a short distance after which it jogs again to the left. The critical limit appears toward the bottom of the table running horizontally below 29% too large. This critical limit is, of course, a section of an ellipse as nearly as it can be represented by whole percentages. In such a table we might enter with a point each combination found in the operation. Those points lying to the southeast of the boundary would be out of control. There would be 13 of them out from among the 30 observations in the hypothetical case so that we could be sure the operation was out of control.

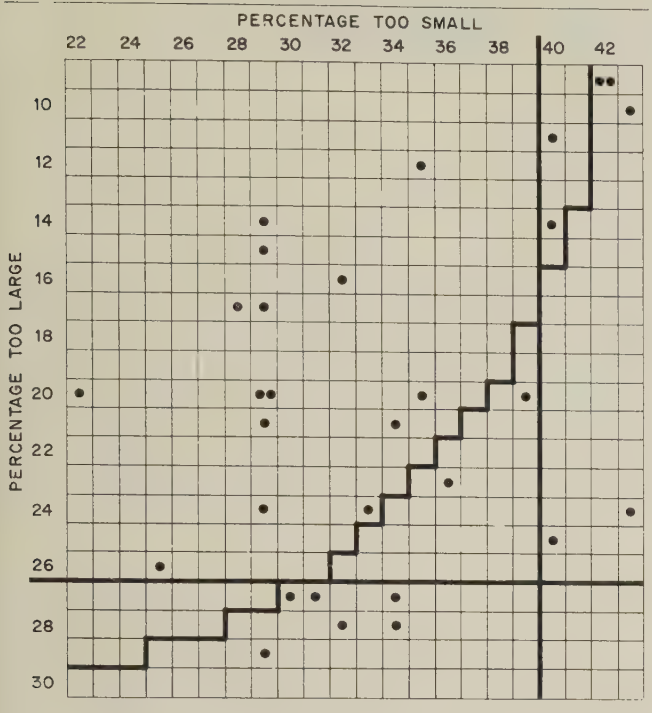
Note that for the case of the imaginary data with mean of 33.77 for small chips and of 19.93 for large we might work by 2-sigma control limits for each separately. We should have for too small a limit of $27.77 + 2(5.64) = 39.05$, say 40 or more, is out. This limit is indicated in Table V by a straight thick line. For too big we should have a limit of $13.93 + 2(6.14) = 26.21$ say 27 or more is out as also indicated in Table V. If now we consider Tables IV or V we see that six values are out of control with respect to percentage too large and seven values are out of control with respect to percentage too small. With respect to the two variables simultaneously 13 are however out of control, i.e., beyond the critical contour. Therefore so far as this illustration goes the contour method is more powerful than either test alone and it will commonly† be so. The advantage of the contour method is, however, greater than this in that the particular values shown as out of control are a better indication of what is the true problem in the present case. To illustrate we note that small 36% and large 23% (lot 22) is out of control when the tests are considered simultaneously but not when they are considered separately. Certain points, for example small 40% and large 11% (lot 29), not out of

† The situation with regard to power is fairly complicated and should perhaps be investigated. At the moment we can see fairly clearly what must be the case when correlation between the two tests is either zero or very high. If there is no correlation in the chance fluctuations of x and y, and if, say, x alone go out of control the simultaneous consideration is probably about as powerful as the control limits for that variable alone. If both go out of control to about the same degree it is presumably more powerful. Consider, secondly, the situation where there is correlation between the chance fluctuations of x and y and in particular the situation as r approaches unity. Then the simultaneous consideration must tend to become identical with the consideration of either alone so long as the disturbance in the process is along the regression line. If the disturbance is off the regression line the simultaneous test must become extremely powerful. Accordingly, we recommend the test, with regard to power, particularly in the case of correlation.

Table IV. Imaginary Data (Percentages) Where the Process Is Out of Control

Lot →	*1*	*2*	*3*	*4*	*5*
Small	31	29	39	43	29
Large	27	14	20	24	15
Lot →	*6*	*7*	*8*	*9*	*10*
Small	29	34	29	40	32
Large	24	21	20	14	28
Lot →	*11*	*12*	*13*	*14*	*15*
Small	30	35	28	34	35
Large	27	12	17	27	28
Lot →	*16*	*17*	*18*	*19*	*20*
Small	39	33	29	42	25
Large	20	24	29	9	26
Lot →	*21*	*22*	*23*	*24*	*25*
Small	29	36	29	43	35
Large	21	23	17	10	20
Lot →	*26*	*27*	*28*	*29*	*30*
Small	32	42	22	40	40
Large	16	9	20	11	25

Table V. Simultaneous Process Control for Percentage Too Small and Too Large in the Case of Imaginary Data Out of Control



control in Table V but which would be if the percentage small were considered alone are actually less improbable and there is less indication of true lack of control. In brief, Table V chooses as indications of lack of control items that have at once too many small and too many large rather than too many small or large alone and thus gives a better indication of the true nature of the process disturbance.

It would seem that the immediately preceding remarks would apply handsomely to the problem of simultaneous control of basis weight and bursting strength. We may then face two situations, one where the basis weight is down and bursting strength is down by the corresponding amount. This situation is the one where disturbance in the process is along the regression line and the simultaneous test will be about the same as a test on either basis weight or bursting strength separately. The second situation is that basis weight is high, the burst is poor for this weight but seems satisfactory because of the great weight. Then the disturbance is off the regression line and the simultaneous test will detect very powerfully the fault in the direction of great weight and the simultaneous fault in the direction of weakness.

In practice one would not approach the matter by calculating a table like III of all the K values but would determine simply the boundaries in order to prepare a control table like V. These boundaries can be obtained from the equation of an ellipse in an x, y field. If much work of this kind were done there might be laid up in the mill laboratory a stock of drawings of ellipses at say the 2-sigma level with governing correlation r at various likely values such as -0.30, -0.35, -0.40, etc., but with the coordinates not fixed and a routine arranged for drawing in the coordinates to satisfy specific conditions of $\bar{x}$, $\bar{y}$, σ_x and σ_y.

SUMMARY AND DISCUSSION

It is suggested that when some general character of a product is indicated by two tests, they should be considered simultaneously in control. Such operation would be particularly profitable when the two tests are correlated. The simultaneous test will be more powerful than either test alone, i.e., must pick up lack of control in a more effective way. It must further give an indication of how the process is out of control, i.e., whether with respect to one test character or to both and so help decisions as to the assignable cause.

It is realized that in the present example the control limits, either in the consideration of the two test values (percentages small and large) separately or in the simultaneous way, may be considered very wide for practice. This objection is valid in that the present boundaries are so wide that serious deviations in operation might be masked by chance fluctuation. This difficulty can, of course, be met by considering not a single sample of chips but the average of the percentage too small and of too large from perhaps four or nine lots of chips at a time. Then the area, as in Table V, for which the process is supposed in control would be reduced to $^1/_4$ or $^1/_9$ of its present state and the process control would become much more strict and powerful.

The procedure suggested is undoubtedly much harder to set up than control for a single variable and it has not been attempted to explain all the steps in detail. The operations are, of course simple to anyone with statistical training. Accordingly, if someone in a mill has a problem where simultaneous control would be valuable he had well learn a little of the theory of simultaneous variation or he had better get statistical advice.

The procedure of simultaneous control suffers from one disadvantage that is perhaps serious, in that one will have difficulty in indicating the element of time in it. Thus, if one has a series of observations that are approaching the critical limit, the fact may not be noticed, at least as the control system has been outlined above. We have thus lost one of the advantages (often a latent advantage) of the Shewhart control chart method.

The proposed procedure has finally one advantage that may prove extremely real in practical operation. This advantage is that one cannot bring a given test back into control at the expense of the other test. Thus, if in the present case two single control charts were employed and the fraction of overlarge chips were too great, an operator might simply adjust the average chip size down a little. Thus he might bring the fraction overlarge just within the control limits and push the fraction of oversmall chips almost out to their limit. The total effect would be apparent control with reference to the single limits. When, however, the matter was viewed against the simultaneous limits, it would be seen that the results, after the adjustment, were just about as bad as before. He would be compelled toward a more difficult adjustment that would result in a more satisfactory product. The same argument bears on two simultaneous tests like tear and bursting strength. How often must a reasonable control of tear be achieved by a change of beating which brings the bursting strength close to its limit and does the total performance of paper no good, whatever?

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Color Measurement and Whiteness

D. L. MacADAM

Measurement of whiteness, for undyed and dye-whitened paper, is discussed in terms of the general method of measuring color. Several proposed formulas for expressing whiteness are compared and discussed.

"Like whiteness, justice is not susceptible of degrees. When they are qualified by 'more or less,' they owe this qualification to the things with which they are mixed."

DANTE, *De Monarchia*

WHITENESS is like justice. Everyone is sure he knows what it is, but as soon as he tries to tell someone else what he knows, he gets all confused. Discussion of specific cases is even worse. As soon as he says, "This is white," or "This is just," he is likely to start an argument. Western man has had so much trouble discussing justice during the past 2000 years that it is hardly polite to mention it any more.

We have not yet reached that stage in the discussion of whiteness. Perhaps you think that is because you are sure whiteness is important. But Socrates, Plato, Aristotle, Cicero, and Dante were all very sure that justice was important. It seems, therefore, that importance provides no guarantee against despair. The discussion of whiteness can escape the fate that befell the discussion of justice only if we can agree on a method of measurement of whiteness. We can escape the maze of words and opinions and passions only if we place the subject of whiteness on a numerical basis.

COLOR

Now, the measurement of whiteness is a specialized application of the science of the measurement of color, and we had best preface a discussion of whiteness with an introduction to the measurement of color.

Things are colored or even white only because we see them, and we see them only because they reflect light to our eyes. We get right down to bedrock, therefore, when we admit that color is a characteristic of light, and that if we want to measure color or whiteness, we must measure something related to light.* However, so long as we talk about optically inert substances, such as paper coated with nonfluorescent materials, we shall be able to devote most of our attention to the reflecting properties of the paper, and shall be only incidentally concerned with the light which it reflects to our eyes. On the other hand, if we take up the subject of fluorescent coatings, we shall have to re-examine the whole subject from its foundation in the fact that color is a characteristic of light, and that color is not merely a characteristic of a substance.

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* For an authoritative definition of color, and a thorough discussion of the principles of the measurement of color, see (*1*), pages 220 to 223. That book is profusely illustrated with color plates, some of which were used as slides in the lecture on which this paper is based.

LIGHT

Light is radiant energy, associated with the propagation of electromagnetic waves, which differ from radio waves only in respect to wavelength. The wavelengths of visible radiant energy, which we call light, extend from about 400 to 700 mmu—about one tenth the diameter of one strand of hair. Variations of wavelength within this range are appreciated as variations of hue. A display of the components of light, arranged according to wavelength, is called a spectrum.

It must be emphasized that color is not merely wavelength, because we very rarely see light consisting of a single wavelength. In almost all cases, the light which we see consists of all these wavelengths put together in various proportions. The color that we see is fundamentally dependent on those proportions, which constitute the spectral distribution of the light. In addition to this, however, the perception of color is dependent on the characteristics of human vision. Those characteristics are so important for the measurement of color that normal values have been established by international agreement. A quick survey of the kinds of colors which are ordinarily encountered in art, industry, and nature will provide an introduction to the use of these data.

White light consists of all of the wavelengths of the visible spectrum mixed together in approximately equal quantities. Plate 5 in (*1*) shows white light entering from the left, and being separated into its constituent parts, by passage through a glass prism. The various components of white light are spread out for view at the right. The prism has done nothing else to the light. No colors have been added, and none removed. The colors present in the original white light are simply separated by the prism. Since the wavelengths blend from one into another continuously without interruption this is called a continuous spectrum. Some peculiar light sources, such as sodium arcs and mercury lamps, radiate only a few isolated wavelengths. When the light from such sources is spread out into a spectrum, those wavelengths appear as lines separated by intervals of darkness. Such spectra are called line spectra.

The intensities of the various components in a spectrum can be measured, and can be shown graphically, as in Fig. 1.† This figure shows spectral distributions for five different kinds of daylight. Figure 2 shows the spectral distribution of the light from an incandescent filament lamp, and also the spectral distribution from a carbon arc. Figure 3 shows the spectral distribution from a fluorescent lamp. Here, a continuous spectrum (the light produced by the fluorescent coating of the lamp) is combined with the line spectrum of the mercury vapor with the lamp. The

† See (*1*), Fig. 68, and Table IV, page 258, for original data.

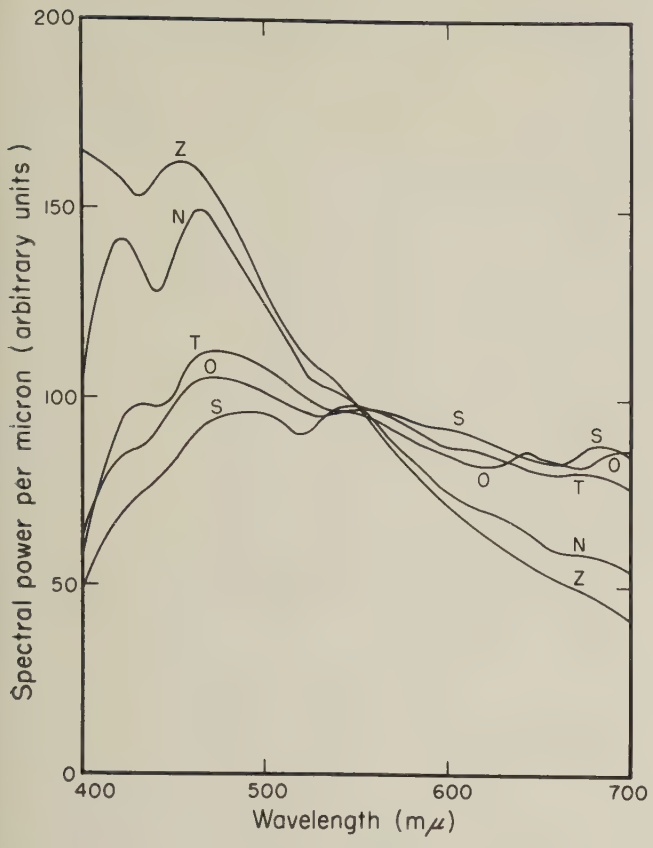

Fig. 1. Spectral distributions of various phases of daylight: Z, zenith sky on clear day; N, north sky on clear day; T, total daylight; O, overcast sky; S, sunlight, only, on clear day

wavelengths of the lines, and their intensities, are represented by the four arrows shown in Fig. 3.

COLOR OF MATERIALS

Curve (a) in Fig. 4 shows the spectral distribution transmitted by a red film. In this, and in subsequent figures, the spectral distribution shown by the curve is relative to the spectral intensity of each wavelength in the incident light. Such relative indication of the spectral distribution is called spectral transmittance. The red film transmits all wavelengths from 600 mmu onward. This is characteristic of red materials and opaque-reflecting materials, as well as transmitting materials. Curve (b) in Fig. 4 shows the spectral transmittance of an orange film. This, too, is typical of orange samples in general, which transmit or reflect all of the red, all of the orange, almost all of the yellow, and even some of the green waves. Curve (c) in Fig. 4 shows the spectral transmittance of a yellow film, which is also typical of yellow materials in general. The fact that yellow materials transmit or reflect two thirds of the spectrum accounts for the high brightness of yellows. Curve (a) in Fig. 5 shows the spectral transmittance of a violet film. This is a rather dark color because it transmits only the dark portions of the spectrum, and these portions quite inefficiently. Curve (b) in Fig. 5 shows the spectral transmittance of a green film, in which the brightest third of the spectrum is transmitted. Again, the efficiency, that is, the maximum transmittance of this film, is not very great. The film is moderately bright, however, because the eye is very sensitive to the central portion of the visible spectrum.

Although these films are typical of the colors named, most colors consist of all of the wavelengths of the spectrum, mixed together in different proportions. The colors seen result merely from the preponderance of the wavelengths in one or another portion of the spectrum. Green grass and foliage and green paper reflect all of the wavelengths of the visible spectrum, but they reflect the green most copiously.

ABSORPTION

Figures 4 and 5 indicated that the incident energy was reduced in intensity at all wavelengths. This is a general phenomenon, and is called absorption. The variation of absorption throughout the spectrum is the cause of most colors. Colors appear because some of the incident wavelengths are absorbed more than others. No new wavelengths are produced, and no wavelengths are increased in intensity when white light falls on ordinary colored materials.

Absorptions more or less confined to the three major portions of the visible spectrum (the red, green, and blue) are the basis of color photography and color printing. Bluish-green materials, such as the film for which the spectral transmittance is shown by curve (a) in Fig. 6, are used to control the amount of red light. Especially when used in color photography, such materials are called cyan. Most of the difficulties and imperfections in color photography and color reproduction arise from the fact that the cyan materials

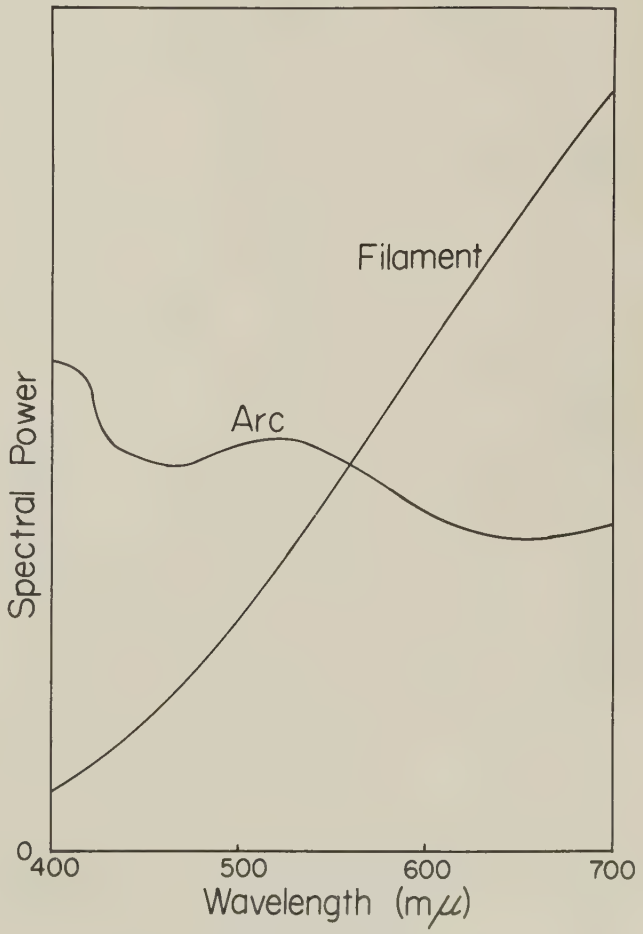

Fig. 2. Spectral distributions of light from incandescent-tungsten filament lamp and from carbon arc

available absorb blue and green light, in addition to the red light which they are intended to absorb.

Yellow materials, such as that represented by curve (b) in Fig. 6, are used in color reproduction for the control (by absorption) of blue light. Curve (c) in Fig. 6 shows the spectral transmittance of the combination of the yellow film (b) laid upon the cyan film (a). The fact that the combination is green‡ is seen here as an obvious outcome of the characteristics of the yellow and cyan film. The yellow film absorbs all the blue light and the cyan film absorbs all the red light. The only light remaining is, of course, the green. Since most bluish paints and dyes transmit green light, it is a very good rule of thumb that the mixture of blue and yellow dyes, inks, or paints will produce green. This is the rule we learned in grade school. However, the green components are present in both of the original colors, and no new color has been produced by the mixture. The appearance of green is merely the result of the removal of the red and blue components by the cyan and yellow materials, respectively.

Figure 7 shows a spectral transmittance curve typical of materials that are used to control the amount of light in the green portion of the spectrum, in color photography and color printing.§ This is magenta. Its blue component is exceedingly important. This is sometimes mistakenly called red, with disastrous consequences, when suppliers of paint or ink take their orders literally and furnish red materials. Reds have little or no transmittance in the blue.§ Consequently, excessively dark reproductions of blue are produced when red, rather than magenta inks, are used for color printing. In color photography, we avoid this misunderstanding by calling this component magenta. Some meticulous workers are even more explicit and call it minus-green, so that the name indicates exactly the desired function of the component. Similarly, yellow is sometimes called minus-blue, and cyan is called minus-red. Color photographs, and magazine and newspaper illustrations in color are almost always composed of these three components—yellow, cyan, and magenta—the purposes of which are to control separately the intensities of the red, the green, and the blue portions of the reflected light. Black is also used in most color printing, for technical reasons with which we need not be concerned here.

‡ See Plate 23, facing page 173 in (*1*).
§ See Plates 22 and 23, facing pages 172 and 173 in (*1*).

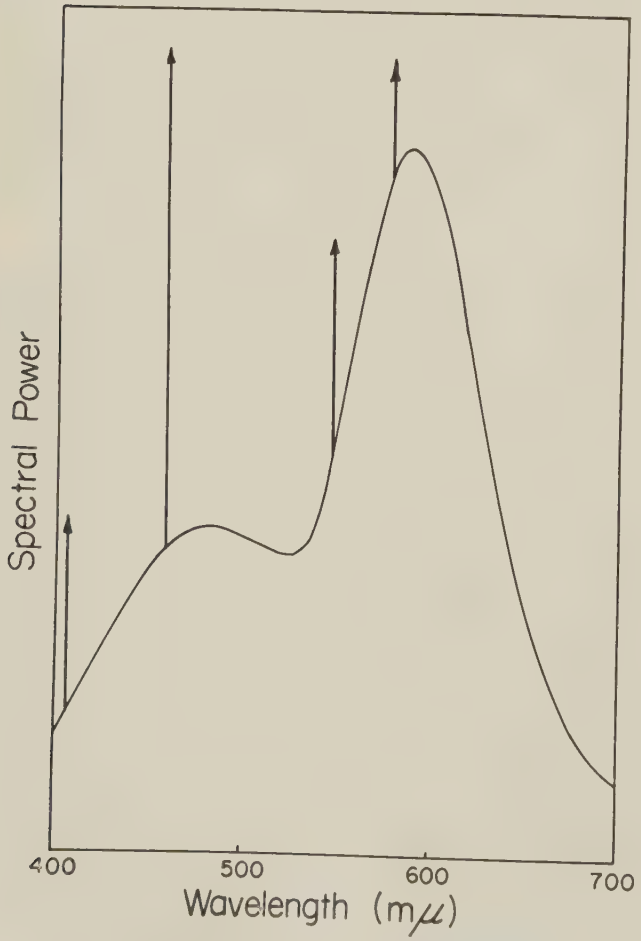

Fig. 3. Spectral distribution from fluorescent lamp

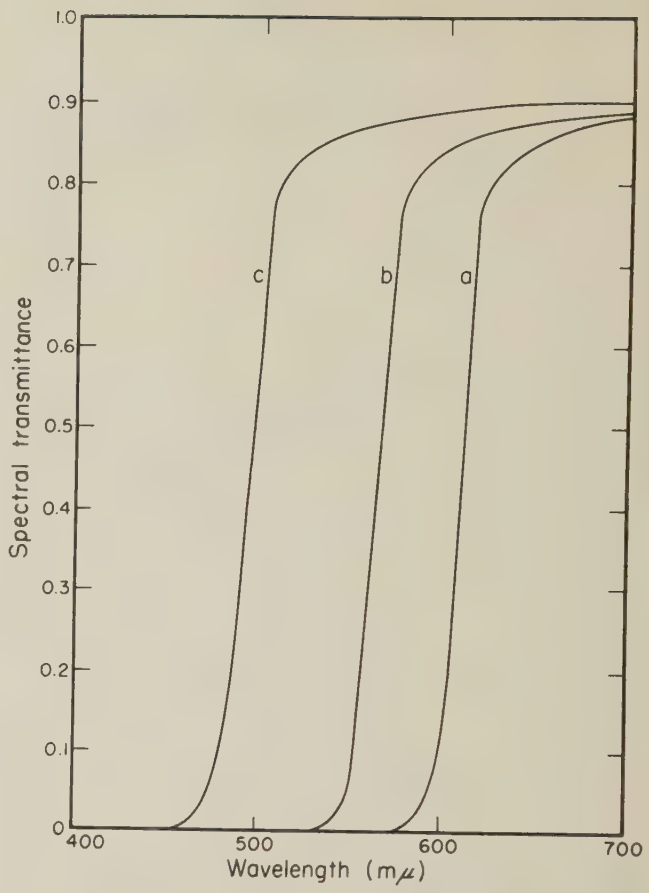

Fig. 4. Spectral transmittances of colored films: a, red; b, orange; c, yellow

COLOR VISION

The principles of color photography and color printing, which have just been sketched, illustrate the fact that color vision is essentially a three-receptor analysis. The basic fact of color vision is that physically different colors can look alike, and that very nearly all colors encountered in nature can be matched by merely adjusting the intensities of red, green, and blue components of a mixture of colored light.

Such a mixture might be produced by three lanterns arranged to project three partially overlapping spots, one red, one green, one blue, on a white screen.‖

‖ See Plate 6, facing page 42 in (*1*).

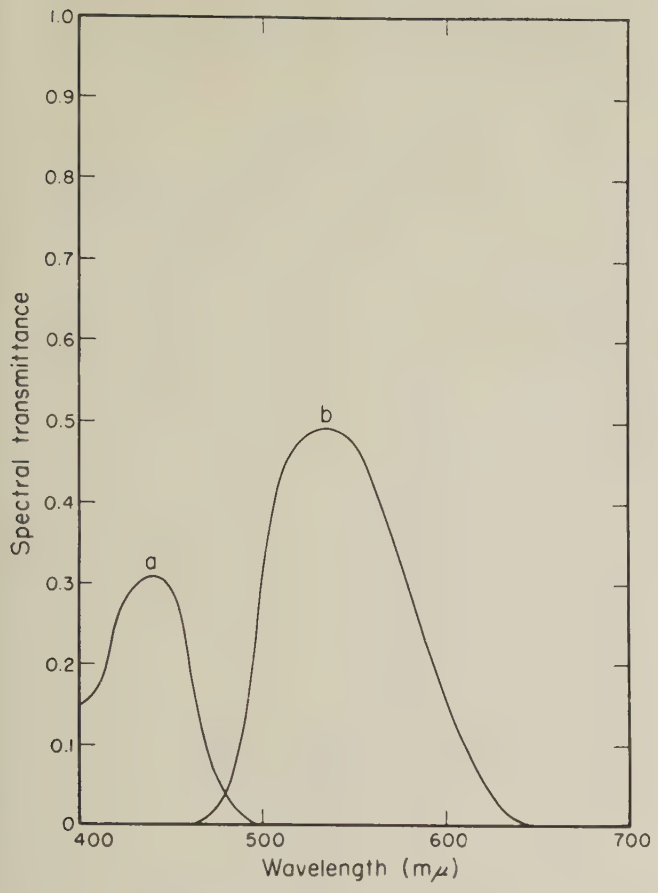

Fig. 5. Spectral transmittances of colored films: a, violet; b, green

Where only the green and red overlap, the mixture would appear yellow; where only the blue and red overlap, the mixture would appear magenta; where only the blue and green overlap, the mixture would appear cyan. Where all three of the color spots overlap, the mixture would appear white. If the intensity of the red is increased and the green decreased, the combination is orange. If the green is then increased and the red decreased, gradually, the combination changes from orange, through yellow, to yellowish-green. In a similar manner, the hues of the cyan and magenta areas of overlap, described above, can be varied. In this way, all the colors of the spectrum can be simulated, and even pink and purple, which do not appear in the spectrum. The white area, where all three spots overlap, could also be varied in tint, merely by adjusting the intensities of one or another, or all three of the overlapping spots of light.

The data of color vision on which color measurement must be based are obtained by systematic experiments in which many colors are matched visually. The observer's task is rather easy and is quickly learned. The intensities of the red, green, and blue components necessary to match equal amounts of energy at each wavelength of the spectrum can be plotted as curves, as shown in Fig. 8. These are called color-mixture functions.

MEASUREMENT OF COLOR

These functions are used in the measurement of color, in the manner shown in Fig. 9. At the upper left is shown the spectral reflectance curve of a sample, and at the upper right is the spectral distribution of the energy falling upon it. The spectral distribution of the light reflected from the sample is given by the product, gotten by multiplying reflectance times energy at each wavelength of the spectrum, as shown in the diagram in the center of the second row. This curve can be multiplied, wavelength by wavelength, by each of the three color-mixture functions, which are shown in the third row of Fig. 9. The three resulting products are shown by the three curves near the bottom of Fig. 9. The areas under these three curves are the amounts of the red, green, and blue primaries necessary to produce a color match with the original sample. These quantities are the fundamental specifications of the color of the sample.

Now, the processes indicated in Fig. 9 must all be carried out with great care and precision. Human eyes are so sensitive to slight tints and shades of color that slight errors in the determinations of the spectral reflectance, or of the arithmetic operations indicated by the several curves in Fig. 9 could easily lose or falsify the color differences which are seen. The curves labeled E, $\bar{x}$, $\bar{y}$, and $\bar{z}$ have all been standardized to very great accuracy by the International Commission on Illumination and by the American Standards Association.¶ The only curve which has to be determined experimentally for each sample is the reflectance curve, R, at the upper left. This curve is determined by the use of a spectrophotometer. Spectrophotometers are available

¶ The basic data, and many supplementary tables designed to facilitate color computations are published in Chapter 8 of (*1*) (pages 254–316). See page 339 for a discussion of American Standards Z58.7.1, Z58.7.2, and Z58.7.3.

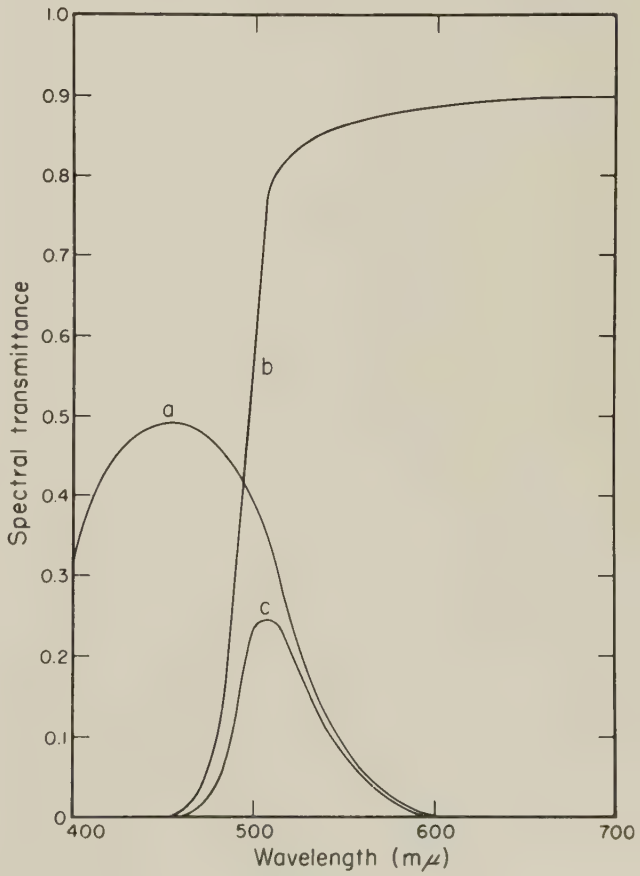

Fig. 6. Spectral transmittances of colored films: a, cyan; b, yellow; c, yellow laid upon cyan

which are adequate for the determination of this curve with accuracy equal to or slightly superior to the sensitivity of the human eye. However, spectrophotometers to be used for the measurement of color must be selected with great care, and they must be maintained and used with corresponding care.

The calculations indicated in Fig. 9 have been mechanized in several ways. Some people employ special attachments to the recording spectrophotometer (*2*). Others employ automatic computing machines, such as are used in some of the larger accounting departments, and which are available to everyone on a service basis (*3*). The calculations can be performed satisfactorily by manual procedures.¶ However, this takes considerable time and skill, so that manual computation is resorted to only when a very few samples are to be done.

Some instruments, called colorimeters, or color analyzers, have been offered, which are intended to carry out the complete process indicated in Fig. 9. Such instruments usually consist of a photocell, or sometimes three photocells, over which are placed suitable filters in an attempt to obtain spectral sensitivities equivalent to the curves $\bar{x}$, $\bar{y}$, and $\bar{z}$. A stabilized light source is included in most of these instruments. For the measurement of the color of a piece of paper, for instance, the sample is placed in the machine, and three indications, X, Y, and Z, are read from electric meters. Although such machines are very convenient and simple to use, the light source and the spectral sensitivities are not exact realizations of the standards, indicated in Figs. 8 and 9, and they are likely to change with age. Consequently, such trichromatic colorimeters or reflectometers cannot be relied upon to maintain color standards. They are useful, however, for day-to-day routine checking of production samples, in comparison with color standards. The color standards themselves can be checked and maintained over months and years only by the use of the best of spectrophotometers and careful calculations.

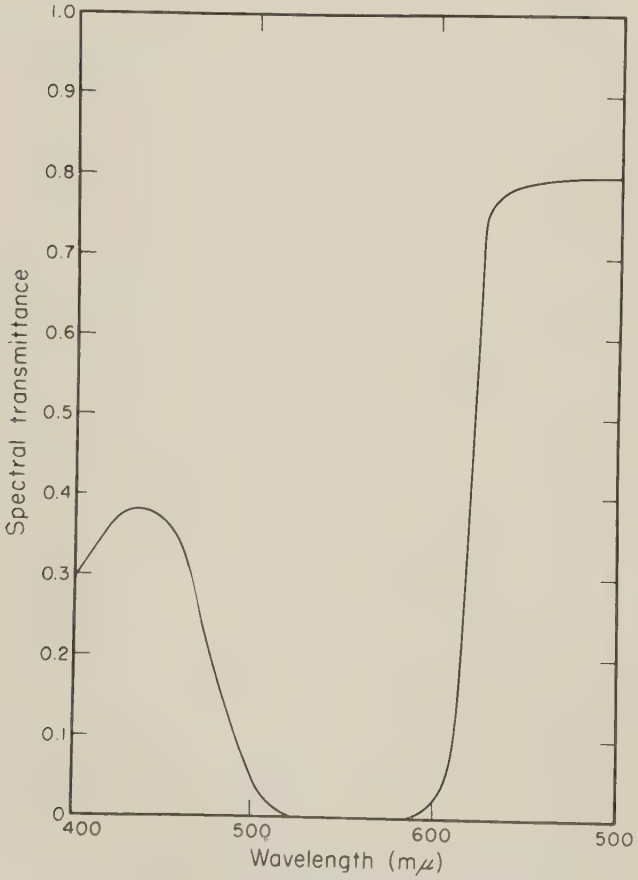

Fig. 7. Spectral transmittance of magenta film

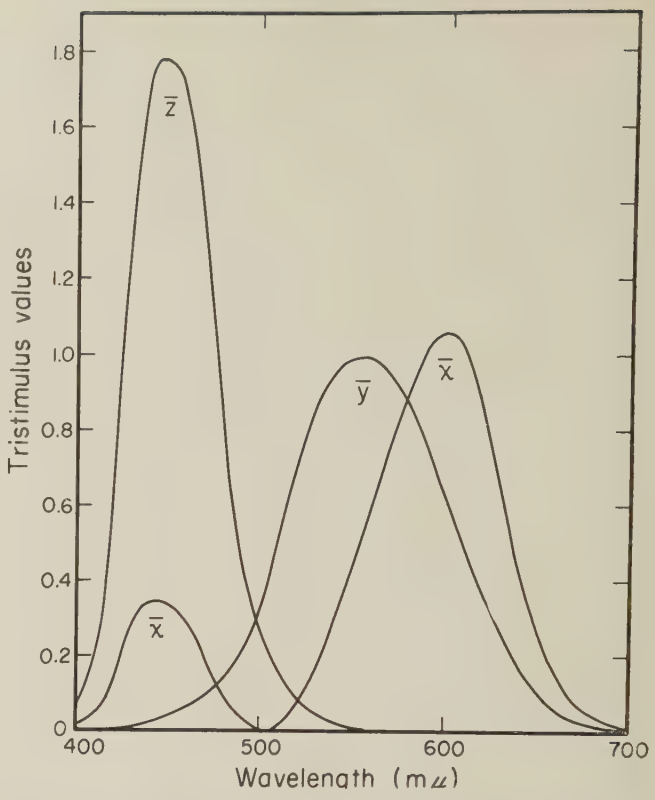

Fig. 8. Color-mixture functions

MAPS OF COLOR

The quantity labeled Y in Fig. 9 is a direct measure of the luminous reflectance of the sample. The color quality of the sample is indicated by the proportions of red and green, X and Y, in the total, $X + Y + Z$. This is indicated in Fig. 10, which shows two perspective drawings of a three-dimensional coordinate system, along which are plotted the values of X, Y, and Z. Luminous reflectance is indicated by the height, Y, above the base plane. The kind of color is indicated by the direction of the point representing the sample, with respect to the origin, or intersection of the three axes, at 0. This direction is indicated by the two x and y values.

These values give you the same kind of information as a cocktail recipe. For instance, the recipe for Manhattans is 2 parts of bourbon and 1 part of vermouth. This determines the quality of your drink, but it doesn't tell you how much to take. You can make or take as much or as little of the concoction as you wish. Likewise, for colors, the x and y values determine the kind of color, but not how light it is. However, it is convenient to have the kind of color or drink specified, independently of its amount.

For colors, we have to consider all kinds of variations of the proportions of red and green in the mixture. If the x and y proportions are used as coordinates, like latitude and longitude on a map, the result is a map of colors such as is shown in Fig. 11. This is usually called

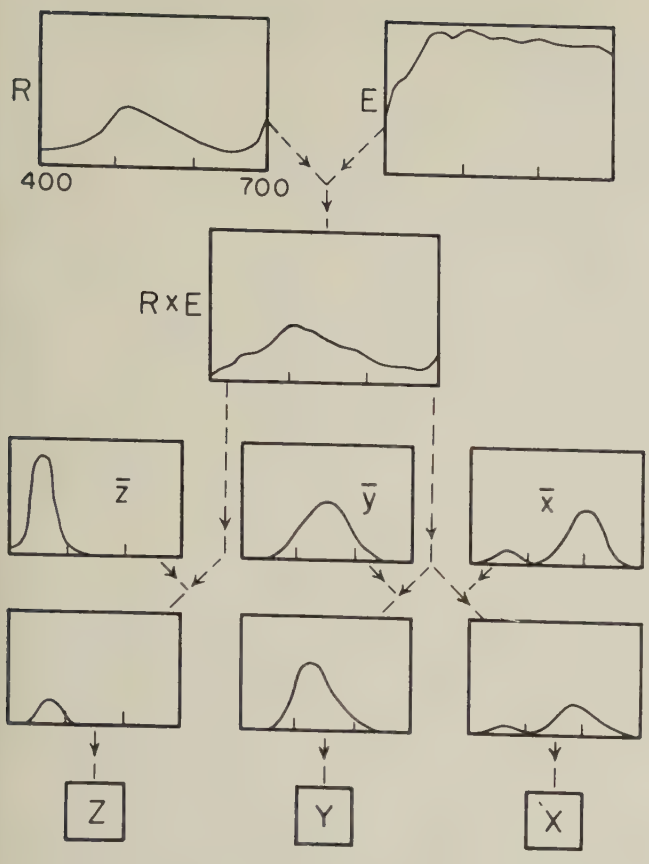

Fig. 9. Schematic diagram of color computations

the *chromaticity diagram.* The curve represents the colors of the spectrum. The numbers indicate the various wavelengths. Plate 24 in (*1*) shows how all ordinary colors are distributed in this map.

White may be considered to be anywhere within a rather big area in the center of the chromaticity diagram. But if we want to measure whiteness, ambiguity must be avoided, and we shall have to agree that standard white is at one precise point on this map. All things considered, it is advisable to select the point that represents the quality of the light with which paper is inspected. For accurate work, and for industrywide exchange of results, the International Commission on Illumination, and also the American Standards Association, recommend a standard light source, called source C, which is an artificial daylight.** In this paper that source will be considered standard white. It is represented by the point (x = 0.3101, y = 0.3163) which represents source C in the chromaticity diagram.

Any other color can be specified with reference to the standard white by the scheme shown in Fig. 12. For the point in Fig. 12 representing the green sample, the straight line from the white point hits the spectrum at about 525 mmu, which is called the dominant wavelength of the sample. The sample point is 19% of the distance from white toward the spectrum curve. For this reason, the purity of the color is said to be 19%. These two numbers, dominant wavelength and purity, describe the kind of color more clearly than do the coordinates, x and y. So, if you want to tell anyone what kind of color you are dealing with, you can tell him in terms of dominant wavelength and purity. This is not merely an academic point. Every color, including the color of so-called "white" paper, requires three bits of information for its complete description. Whiteness formulas condense these three specifications into one, called whiteness. But they do so only by throwing away information. During the past 21 years, the wheel has come full circle. In 1933, in measuring whiteness, the author reported dominant wavelength, purity, and luminous reflectance only to be told that the customer wanted one number, not three. So, after research, and some compromise with principles the author acceded to that demand (*4*). During subsequent years, other workers in this country and abroad have improved on his solution of that problem. However, this year, at the Spring Meeting of the Optical Society of America, one speaker was emphatic in stating that single-number specifications are not adequate, even for commercial use (*5*). Although it is convenient to have a single numerical scale for whiteness, aren't there times when you want to know also—what tint; how much tint; and how bright? If so, don't forget dominant wavelength, purity, or luminous reflectance.

Let us return to the representation of colors on the color map, which is often called the chromaticity diagram. Like flat maps of portions of the earth, this map of colors distorts the distances between colors, as shown in Fig. 13. This diagram shows, by each closed curve, the locations of the points representing all colors which are equally noticeably different from the color indicated by the center of each cross. The distortions of the map of colors are indicated by the fact that the curves on which these points are located are not equal-size circles, but are ellipses, which vary greatly in shape and size from one part of the map to the other.

Since some maps of the world are better than others in this respect, it might be expected that some improvement might be obtained if a different projection of the map of colors were used. This has been attempted by a number of workers. One of the more successful attempts is shown in Fig. 14. But, even on this map,†† the circles which represent equal color distance from the central colors are distorted, as shown in Fig. 14. However, the distortion is not so bad, and particularly in the neighborhood of white, this map is very good. This is known as

** See (*1*), pages 256, 257, 267, 274, and 294, for the exact definition and working data for standard source C.

†† See (*1*) pages 301 to 303, for definition and more precise portrayal of this transformation of the standard chromaticity diagram.

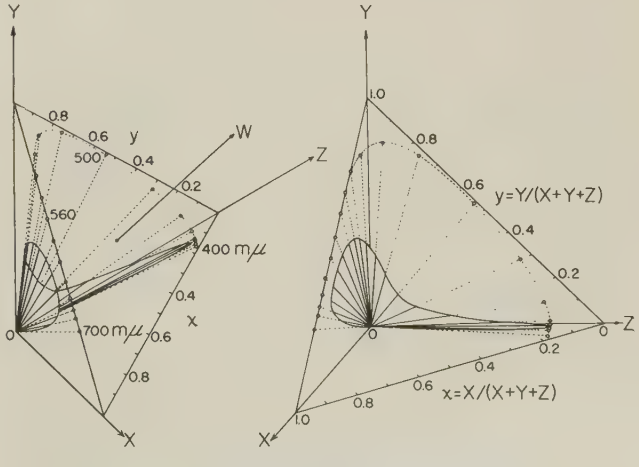

Fig. 10. Perspective drawings of color space

the uniform chromaticity scale diagram (*6*), and has been used in several formulas for the evaluation of whiteness. The kind of color variation from perfect white can be measured as an ordinary distance in this diagram, and that distance has been used in some of the formulas for whiteness.

If we confine our attention to the neighborhood of white, as we can so long as we are talking about the evaluation of whiteness, a perfect map can be obtained for that small portion of the color diagram just as a perfect map can be obtained for a city, or even a state. Such a map, which has no distortions in the neighborhood of white, is shown in Fig. 15 (*7*). Distances measured from the white point in this diagram could be used in the formulas for whiteness. Although this has not been done, it could be. There is, after all, no reason why you, who are concerned only with whiteness, should be troubled by the difficulty of representing colors of the highest purity on a flat, undistorted map. It is quite sufficient for the purpose of whiteness measurements to use a perfect map of the neighborhood of white and to let other people worry about the highly saturated colors.

WHITENESS

Undyed papers and white pigments have more or less high, nearly flat, spectrophotometric curves, which differ primarily in the amount to which the curve dips down in the blue region of the spectrum, as shown in Fig. 16. The more the curve dips in the blue region of the spectrum, the yellower the paper appears. And, of course, the greater the yellowness, the less good the paper is as a white. For this reason, the first fairly successful method of measurement of the whiteness of papers was a measurement of the reflectance in the blue region of the spectrum. I believe this is called "brightness" in the paper industry.‡‡ This method is quite good, so long as dyes are not used for the improvement of the whiteness. It is better than a measurement based on the sensitivity of the eye, which is also shown in Fig. 16.

‡‡ This use of the term "brightness" should be distinguished from the attribute of color sensation which is defined as brightness on page 42 of (*1*).

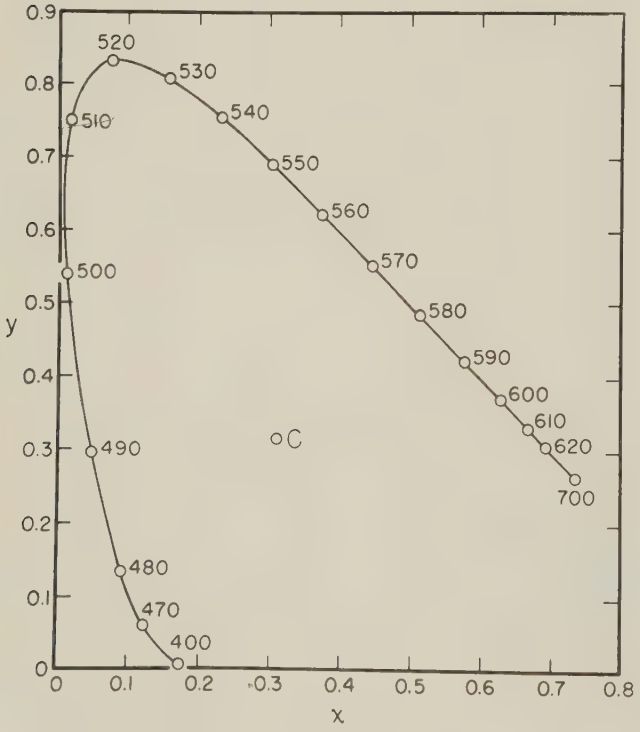

Fig. 11. Chromaticity diagram

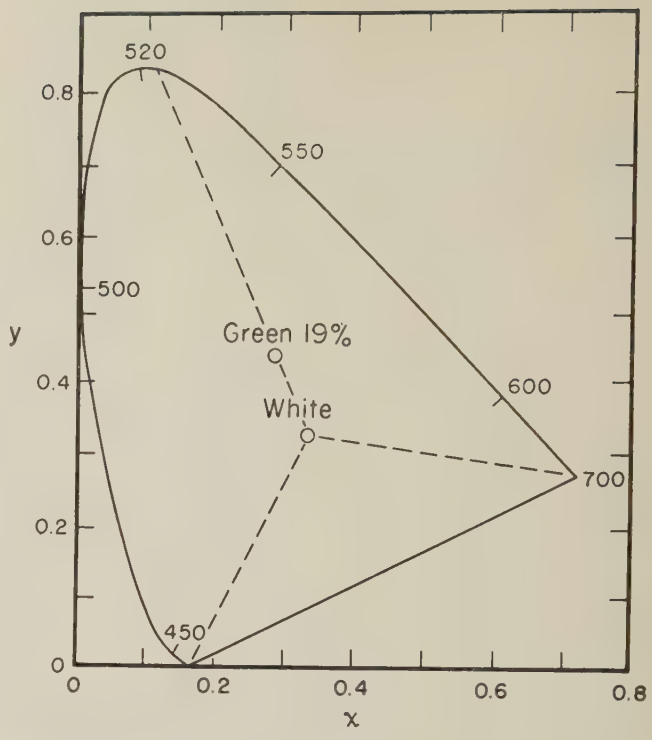

Fig. 12. Dominant wavelength and purity

As shown in Fig. 17, the effect of blue dyes is to reduce the reflectance in the red region of the spectrum so as to make it more nearly equal to the reflectance in the blue region of the spectrum. Blue dyes counteract more or less successfully the yellowish appearance of the undyed paper or coating, but they do so at the expense of the overall reflectance or lightness of the paper. From this arise two new problems. The first is fundamental and is expressed by the question, "How do you know when you have added enough blue dye?" A little bit is certainly an improvement. It reduces the yellowness of the paper without seriously decreasing the lightness of the paper. However, in this, as in drinking Manhattans, it is not true that if a little is good, therefore more would be better. A point is reached, sooner or later, at which the yellowness is all, or almost all, eliminated. Additional blue dye serves mainly to decrease the lightness of the paper, making it first grayish, and finally bluish. Neither of these tendencies produces any improvement in the whiteness of the paper. Quite the contrary! A successful method of measuring whiteness should indicate the optimum amount of blue dye to be used, and should sound an alarm before too much blue dye is added.

The second problem created by the use of blue dyes for whitening papers is that it renders useless the first and rather successful method of measuring whiteness, which was the measurement of the reflectance in the blue region of the spectrum. The reflectance in the blue region is hardly affected by the addition of blue dye. What slight effect it has is a decrease of reflectance in that region, so that, although the whiteness is increased by the first small additions of blue dye, the whiteness

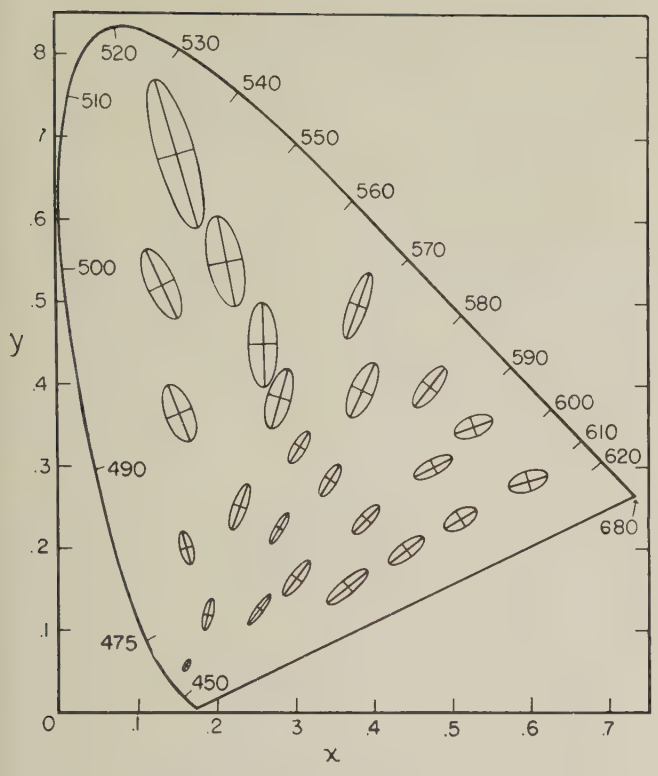

Fig. 13. Ellipses showing equally noticeable color differences (from centers) in standard chromaticity diagram

measured by the reflectance in the blue decreases slightly. Therefore, that method of measurement is only applicable to undyed papers and coatings. It fails on two counts when blue dyes or other whitening agents are used. First, it does not indicate that bluing increases whiteness, and secondly, it does not indicate when enough bluing has been used and that additional bluing would be disadvantageous.

Another method of measuring whiteness has been to use a photocell with a filter designed to give the same spectral sensitivity as the luminosity of the human eye. This is the curve in Fig. 16. It gives most weight to the green region of the spectrum, and much less, although some weight, to the blue and red regions of the spectrum. This method of measurement of whiteness would be all right if no tints were encountered, either yellowish or bluish. However, this method of measurement does not penalize the grade of a paper for yellowness or for blueness. Consequently, such a simple measurement of whiteness fails both for the undyed yellowish tints of papers and also for the bluish tints resulting from the excessive use of whitening agents. Stephanson (*8*) and Harrison (*9*) based whiteness formulas on the reflectances in the blue and red regions of the spectrum, as shown in Fig. 17. Although fairly good results were obtained with Stephanson's formula, it does not indicate when enough or too much blue dye has been used. Addition of blue dyestuff results in a rapid decrease of red. Papers which have a noticeably blue tinge are incorrectly given a score that indicates that they are whiter than those which are visually better whites (*10*).

WHITENESS FORMULAS

In the evaluation of whiteness, it is necessary to play off the amount of tint, whether yellow or blue or green or pink, against the amount of luminous reflectance or lightness. In 1933, when we were trying to establish a measure for the amount of whitening produced by laundry soaps, it quickly became apparent that we would have to measure at least two quantities, the luminous reflectance or lightness of the material and also the amount of tint, or difference from the chromaticity of perfect white (*4*). As a result of our work, D. B. Judd (*11*) of the National Bureau of Standards, who was interested in the problem of measuring the whiteness of papers, suggested the following formula for whiteness: $W = \sqrt{Y - 6700(\Delta s)^2}$, where Y is the luminous reflectance of the paper relative to magnesium oxide taken as unity, and Δs is the deviation of the color quality, or chromaticity, of the sample from the white point, as measured on the uniform chromaticity-scale diagram, such as is shown in Fig. 14. This was the first formula in which the lightness was penalized according to the color content. The penalty is not severe for slight tints, but squaring Δs imposes severe penalties on all strong tints. Judd recommended magnesium oxide as perfect white, which is equivalent to the standard described above: that is, the color of the illumination falling upon the sample. Judd's formula was quite successful for nearly white papers. It indicated an optimum amount of blue dye to be used to produce maximum whiteness, but that amount of dye was not exactly confirmed by visual judgments (*10*). Judd's first formula gave imaginary values of whiteness when the tint (Δs) became very great. Is this bad? Such colors are definitely not whites, and it could well be argued that no value of whiteness should be given to them. However, other people have criticized Judd's formula because of this, and they and Judd, himself, have proposed other formulas which avoid this difficulty. Three of these are discussed below. These formulas can all give "whiteness" values for the reddest, or the greenest, or the blackest papers you can make. Isn't this slightly ridiculous? Has whiteness, like justice, no limit of degradation?

During the war and for a short postwar period when American publications were not available in Europe, Selling (*10*), in the Netherlands, developed two formulas which were not published until 1949. Selling's first formula was $W = 100\{1 - \sqrt{(\Delta\sqrt{Y})^2 + 32(\Delta s)^2}\}$, where $\Delta\sqrt{Y} = 1 - \sqrt{Y}$. His second formula was a simplification of his first: $W = 100\{1 - \sqrt{(\Delta Y)^2 +$

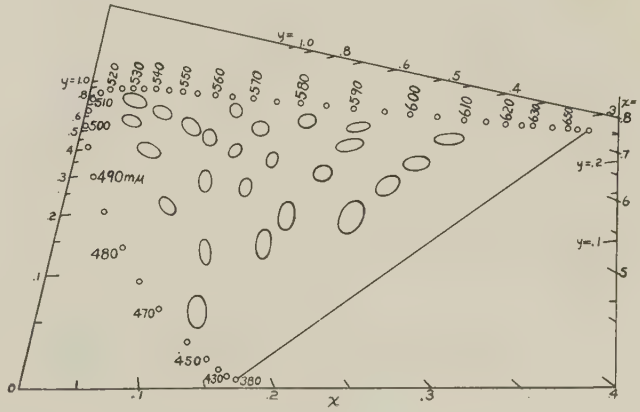

Fig. 14. Ellipses showing equally noticeable color differences in Judd's uniform chromaticity-scale diagram

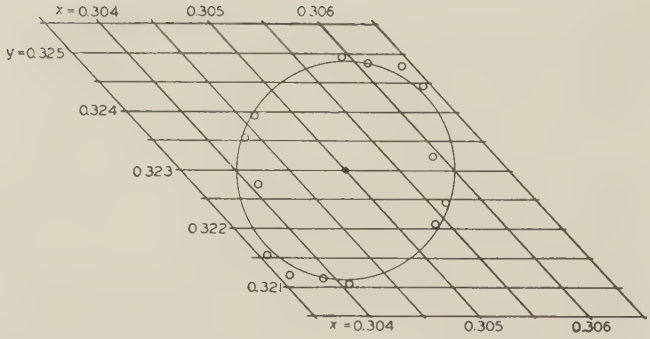

Fig. 15. Undistorted color map in neighborhood of white

$\overline{120(\Delta s)^2}\}$, where $\Delta Y = 1 - Y$. These formulas were both more successful than Judd's 1935 formula in comparison with visual gradings of white papers (*10*).

Early in the war, Judd devised another whiteness formula (*12*). He wrote his formula in terms of readings from the Hunter color difference meter (*13*). This meter is a three-filter photoelectric reflectometer which has been rather widely distributed in this country. For those who have such an instrument, Judd's formula for whiteness can be recommended as a successful method of grading. However, the author has converted Judd's formula so that it is in terms of distances in the UCS diagram: $W = 100\{1 - \sqrt{(\Delta\sqrt{Y})^2 + 40\sqrt{Y}(\Delta s)^2}\}$. The coefficient, 40, is based on a redetermination by Selling (*10*). The resemblance between this formula and Selling's first formula is striking. The only difference is that the chromaticity difference (Δs) is multiplied by the fourth root of the luminous reflectance. The effect of this is negligible for near-whites. Selling tested Judd's and Selling's formulas on 20 different samples. The samples were arranged by both in exactly the same order according to whiteness (*10*). For both formulas, the correlation of the whiteness values in comparison with visual gradings was 0.95.

USE OF WHITENERS

The Selling and Judd formulas were further tested by Selling by use of a special series of esparto paper blued with Alizarine Irisol. The papers were dyed with various concentrations. The reflectance curves were measured on a spectrophotometer and the color specifications were calculated. The resulting colors are indicated in Fig. 18. The samples were submitted to each of 33 observers. Each was asked to decide which sample in each series gave the best whiteness impression. The whiteness values calculated from the Selling and Judd formulas are listed in Table I, together with the frequency of choice as the best white. This table is abridged from a table published by Selling (*10*). The second Judd formula and the first Selling equation show results which are consistent with the visual grading. An increase of dye concentration beyond the optimum dye content is judged visually as a much more distinct decrease of whiteness than if the dye concentration is lower than the optimum value. This phenomenon does not appear in the calculated whiteness values. From this we may judge that there is yet room for improvement in the whiteness formulas.

Table I
(Esparto paper, blued with Alizarine Irisol)

Dye concn., %	Whiteness values according to Judd I	Selling I	Selling II	Judd II	Choice frequency
0	Imaginary	75.6	53.4	75.2	..
0.01	Imaginary	76.2	54.8	75.7	..
0.03	Imaginary	77.8	58.4	77.7	..
0.07	Imaginary	78.1	59.1	78.1	2
0.09	Imaginary	78.6	60.3	78.6	..
0.10	Imaginary	78.8	60.6	78.7	..
0.11	Imaginary	78.6	60.6	78.6	6
0.14	0.368	79.0	61.6	79.0	9
0.17	0.593	78.8	61.6	78.9	11
0.18	0.605	78.6	61.3	78.7	3
0.24	0.748	78.0	60.7	78.0	..
0.26	0.763	77.9	60.7	77.9	..
0.40	0.361	74.4	54.9	74.3	..
0.60	Imaginary	69.0	45.6	68.7	..

An easy way to estimate the dye concentration yielding optimum whiteness for a given pigment and blue dye is to plot the lightness against the color saturation (Δs). In Fig. 19, this is done for the samples represented in Fig. 18 and Table I. The ordinate measures the $\sqrt{Y}$, and the abscissa measures the color separation Δs weighted in accordance with Selling's first formula. The points representing the samples with increasing dye content are indicated. The graph consists of two straight lines. The upper one is for yellowish tints, the

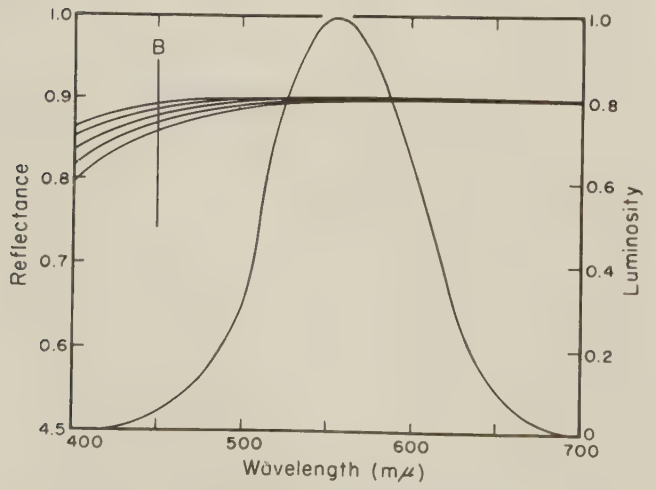

Fig. 16. Spectral reflectance of undyed papers; luminosity curve for normal human eyes

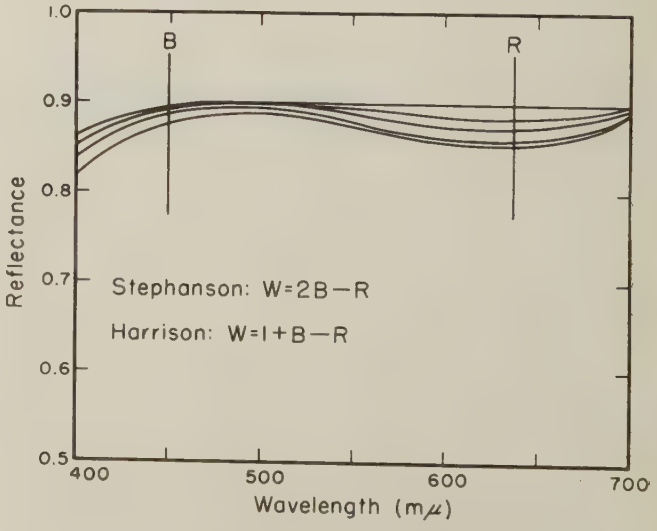

Fig. 17. Spectral reflectance of blue-dyed papers

lower one for bluish. The point of tangency of the upper line with the circle drawn around the point representing perfect white (at the upper left corner) indicates the sample of optimum whiteness. The dye concentration needed to give this optimum value can be interpolated between the nearest available points.

A comparison between two competitive whitening agents can be made in the same diagram. The purpose of the addition of a whitening agent is to decrease the yellowness of the paper with as little decrease of lightness as possible. Therefore, the angle between the upper straight line representing the series of samples and the lightness axis can be taken as a measure of the effectiveness of a dye. The smaller this angle, the less effective the dye.

Fluorescent whitening agents, which have become much more common recently, complicate the spectrophotometric problem, but do not change the problem of whiteness formula. Fluorescent whitening agents are rarely themselves white. They cause tints that are at least as noticeable as those caused by blue dyes. Such tints must be penalized, in the evaluation of whiteness. The amounts of fluorescent whitening agents that can be used, therefore, are limited in a way similar to the limitation of the amount of blue dye that can be used to produce white.

Attainment of the highest degree of whiteness is something like climbing a mountain. Both are hard work, and, when you get to the top, there is no place to go but down. The use of bleaches and blue dyes is like climbing a well-weathered old mountain with rounded top. The use of fluorescent whitening agents is like climbing a very sharp peak. You can probably reach a higher altitude on the latter, but it's very easy to fall off the top, in any direction, and then you go down quickly. For paper whitened with fluorescent materials, such an accident can happen as a result of a very slight change in the quality of incident light. We cannot be

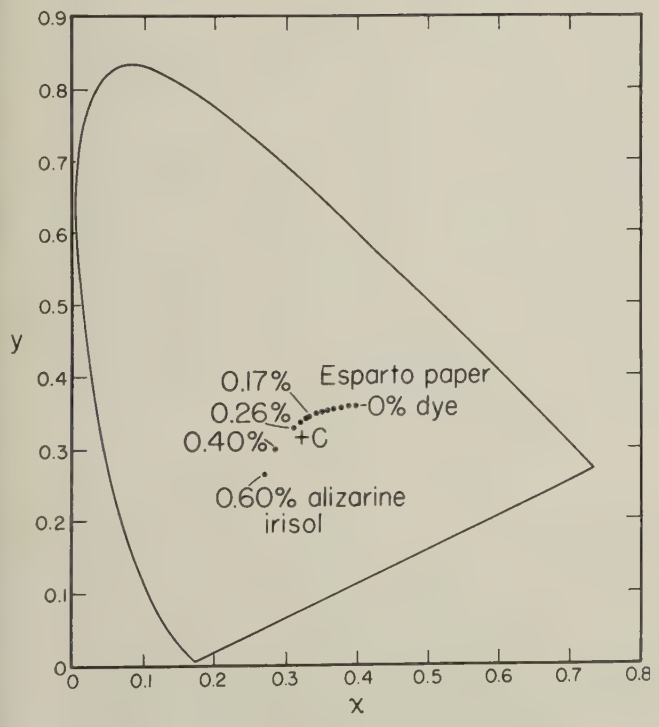

Fig. 18. Chromaticities of blue-dyed papers

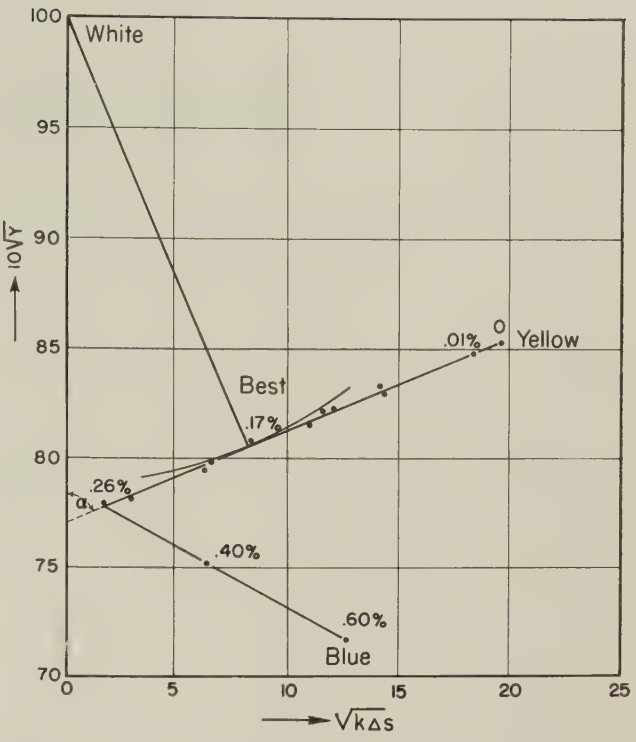

Fig. 19. Whiteness diagram, showing effectiveness of blue dyeing and method for determination of optimum concentration

sure that people will examine white papers only in a standard quality of illumination. Fluorescent whitening agents can cause very noticeable and peculiar tints in illumination that differs very slightly or not at all, visually, from the standard light for which the whiteness was adjusted to a maximum. Such peculiar sensitiveness to visually trivial variations of quality of illumination is often as objectionable as the actual tints that result from nonstandard lighting.

We may not be able to get so high on the old, weathered mountain, or with the bleaches and blue dyes. But when we get to the top, we are not so likely to fall off. And if we should slip, we cannot slip far. These conclusions can be checked quantitatively, by applying the formula for whiteness to investigations of the effects of fluorescent and nonfluorescent whitening agents in the preparation of white papers.

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Dye Adsorption on Wood Pulp

IV. Note on Effect of Drying of Pulp on Specific Dye Adsorption

EDWARD F. THODE, ANDREW J. CHASE, and YEE HU

Determinations of specific dye adsorption have demonstrated that the external surface of sulphite pulp decreases as a smooth function of moisture content of the pulp at termination of drying. The decrease in strength of the unbeaten pulp as drying progresses is likewise shown to be a function of the specific dye adsorption. These results are interpreted as meaning that the phenomenon of "irreversible cornification" (Jayme) greatly affects the external surface of the wood pulp fiber. It is concluded that the potential of the fiber for interfiber bonding is markedly reduced on drying simply because of this irreversible reduction in external specific surface.

In earlier papers in this series (*4*), attention was called to the marked reduction in specific dye adsorption noted when a given slush pulp was dried and then reslurried without significant beating or defibrillation. This phenomenon was earlier reported by Jayme (*1*) as a result of a series of what were essentially *ab*sorption experiments. Lyne and Gallay (*2*), in a recent paper, summarize the knowledge of the effect of drying and heating on the swelling of cellulose fibers and on the strength of paper. These authors present data showing a linear relationship between the per cent decrease in burst on drying pulp and the per cent pulp solids present at the termination of drying. Although the effect of drying of pulp in reducing paper strength is well known and has often been reported, Lyne and Gallay appear to have been the first to present comprehensive quantitative information.

It was felt that quantitative data on the relationship of decrease in fiber surface to the decrease in paper strength on drying would be of interest as a corollary to the work of Lyne and Gallay. Since the dye adsorption technique, while not absolute, is thought to give good comparative data relating to changes in external specific surface, it was decided to obtain dye adsorption data on a sulphite pulp which had been dried under various conditions.

PROCEDURE

The dye adsorption procedure employed was the same as that described in a previous paper (*4*).

Air drying of the bleached sulphite pulp used was carried out at a constant temperature of 68° F. and a constant relative humidity of 50%. It was found that the dye adsorption test was extremely sensitive to variations in sheet moisture content. Thus it was necessary to dry the samples for study under very carefully controlled conditions in order to obtain reproducible results. Handsheets were formed according to TAPPI Standard T 220 m-46 (*3*) through the first pressing step. The pressed sheets were retained between blotters until a sufficient number had been prepared and then the entire number, usually 20 to 28, were transferred as rapidly as possible to a drying rack in a constant humidity room. This rack was fashioned in the form of a coarse grid made from $^1/_{16}$-in. rods spaced 2 in. apart. Successive horizontal layers of this grid were separated by a vertical distance of 4 in. The drying rack was located at a position in the room where a horizontal air velocity of about 3 in. per sec. prevailed because of the draft induced by the air conditioning system. By following this drying procedure it was possible to obtain a reproducible moisture content versus time of drying relationship and it was likewise possible to dry uniformly the necessary number of handsheets to any desired moisture content.

It was found in preliminary experimentation that reproducible results could not be obtained on thick pads because of nonuniformities in the moisture content through the thickness of the pads. It was also found that drying under forced draft of 3 to 5 ft. per sec. air velocity was undesirable because a reproducible moisture content versus time relationship was not obtainable.

For oven drying and heating experiments, sufficient handsheets for a single determination were placed horizontally on wire screens inside a Thelco natural circulation laboratory oven.

In both air drying and oven drying experiments, representative samples for moisture determination were placed in weighing tubes and the tubes immediately covered at the end of the predetermined drying period. The remainder of the stock was then immersed in a large excess of water and allowed to soak for 24 hr. before the dye adsorption test. In the case of handsheet preparation for physical tests, the dried pulp was similarly immersed in water for 24 hr. before the standard handsheet procedure was carried out.

RESULTS AND DISCUSSION

Figure 1 shows the differing relationships between dye adsorption and moisture content for sheets dried at various temperatures. For sheets dried at 100°C. the relationship is apparently linear, but the data at 65°C. show a parabolic tendency which becomes more pronounced in the 20°C. (air drying) runs. Figure 2 gives the relationship between dye adsorption and the various physical properties of the reslurried air-dried pulp on semilogarithmic coordinates. As was

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This investigation has been a project of the Fundamental Research Committee of TAPPI, and was financed through Research Grants Nos. 31 and 53. The experimental work was carried out at the University of Maine, using the facilities of the Department of Chemical Engineering. The cooperation of the University of Maine Pulp and Paper Foundation is gratefully acknowledged.

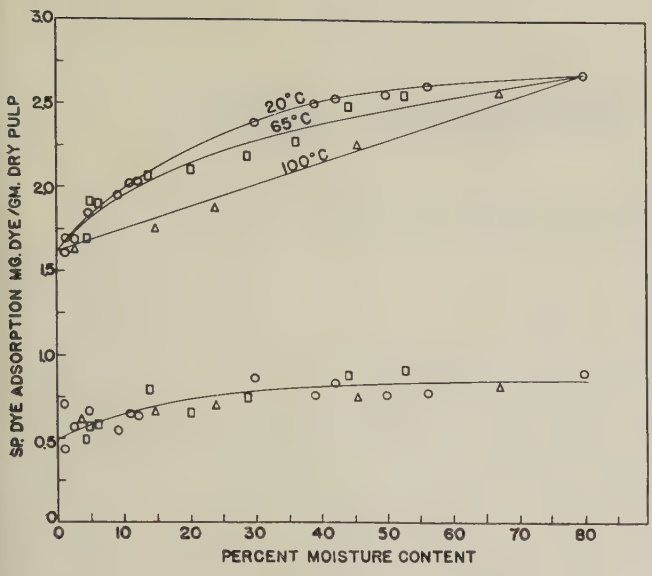

Fig. 1. Variation of specific dye adsorption with moisture content of pulp dried at various temperatures (lower curve represents runs without KCl)

found in the case of other phenomena reported previously, the values of these vary as a regular function of the logarithm of the specific dye adsorption. The last figure (Fig. 3) shows in four different plots the influence of moisture content of the dried pulp (actually expressed in terms of per cent pulp solids) on the burst, tensile, bulk, and folding endurance of the paper made therefrom. The data of Lyne and Gallay as well as that of the present authors are shown. A good correspondence in trend of the data is noted between the two investigations. That Lyne and Gallay obtained a greater loss in properties on drying than did these authors may most likely be ascribed to differences in the pulps studied and the water used in handsheet making.

Several conclusions may be drawn from these data: first, there is apparent confirmation of the idea that the loss in strength of dry pulp is caused by a decrease in the surface available for interfiber bonding. Second, the influence of temperature of drying on surface changes is clarified. By our tests, the higher the temperature of drying, the greater the reduction in surface by the time a given moisture content is reached; but, since the rate of change of area with decreasing moisture content becomes greater as moisture content becomes less for drying below 100°C., these differences virtually disappear by the time the "air-dry" state is reached. Third, the relationship between strength and specific dye adsorption for any given pulp appears to hold for various conditions of dryness as well as during the course of beating.

It is of interest to note the correspondence between the data herein reported and those of Jayme (*1*). Jayme estimated from swelling measurements 35% loss in (total) surface in going from the slush to the oven-dry state. That figure is in very good agreement with the per cent decrease in dye adsorption, and thus in external surface, noted in the present work.

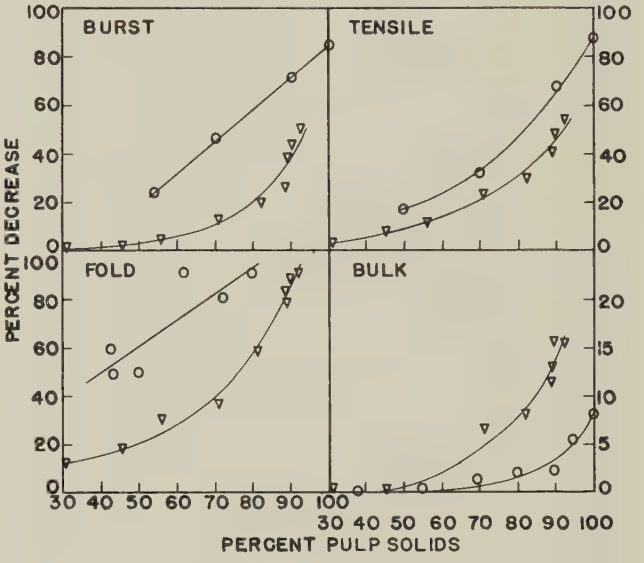

Fig. 3. Effect of moisture content on various physical properties of unbeaten pulp (circles—data of Lyne and Gallay (2); triangles—data of this investigation)

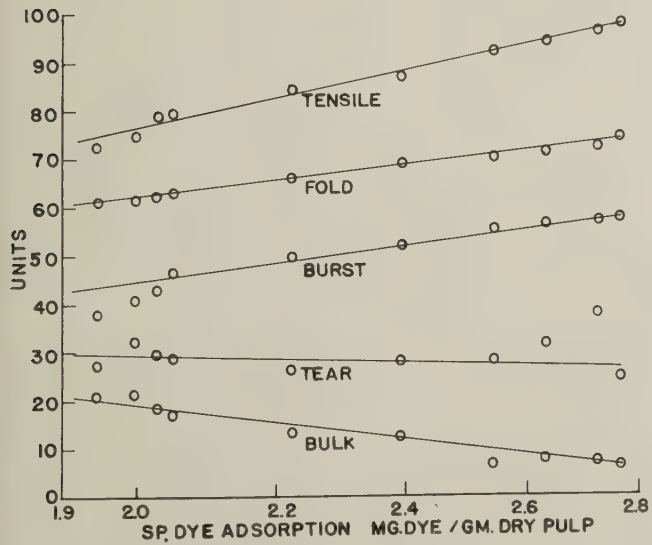

Fig. 2. Relationship of specific dye adsorption to physical properties of reslurried air-dried pulp

SUMMARY

It is concluded from the results of dye adsorption experiments that the phenomenon of irreversible cornification or closing of minute fissures in wood cellulose fibers upon drying greatly affects the external specific surface of the wood pulp. The decrease in strength properties of dry pulps as compared to slush pulps is attributed entirely to this shrinkage in external surface and consequent reduction in area available for interfiber bonding.

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The Chapman Printing Smoothness Tester

I. Basic Development and Recent Modifications

S. M. CHAPMAN

The importance of smoothness as a printing property of paper has long been recognized. Depressions in the surface of the paper may fail to touch the ink film on the printing surface and the resulting lack of ink transfer leads to white areas in the print. A measure of the amount of contact with a smooth surface would therefore seem to be a desirable method of measuring smoothness from the standpoint of its effect on printing. During printing, paper is subjected to considerable pressure which, due to the compressibility of the paper, leads to increased smoothness. Since it is difficult to correct for this compressibility effect it would appear to be desirable to measure the smoothness under pressures comparable to printing pressures. Printing smoothness is therefore defined as the fraction of the surface which can be brought into contact with a smooth surface pressed against it under pressures comparable to printing pressures. An instrument designed to measure this property by an optical method was disclosed in a previous report from the Pulp and Paper Research Institute of Canada. The present paper reviews the theory of the method and discusses its theoretical shortcomings. One of these is the fact that the paper surface must make optical contact with a glass surface in order to register as contact. In printing, on the other hand, the paper surface need only approach the printing form to within the thickness of the ink film. This fairly fluid film can move about under the printing pressure and flow into very small depressions in the surface. Some experiments were carried out in which attempts were made to simulate, in the test, this action of the ink film in printing. Recent modifications to the original instrument are also described. These improvements have resulted in making it direct reading and more readily standardized.

In order to provide the printer with a product suited to his needs, the paper industry must be able to control those properties of the paper which influence its printing behavior. This requires that means be available for measuring these properties.

It is generally conceded that smoothness is one of the most important properties of paper from the standpoint of faithfulness of reproduction in printing. This is particularly true in the case of letterpress printing, probably the most used process at the present time. The ink will not be transferred from the form to the paper unless the two can be brought into intimate contact. Small depressions in the surface of the paper will prevent this contact and result in white, unprinted areas in the print.

The importance of smoothness as a printing property of paper has been stressed by Bekk (*1*), Prior (*2*), Larocque (*3*), Bendtsen (*4*), Sankey (*5*), and others. This paper will not attempt to describe the history of such measurements. The unsatisfactory results obtained have been recognized for a considerable time and discussed in various papers (*6–10*).

The author of this paper presented a paper to the Technical Section, CPPA in 1947 (*10*) disclosing a new approach to the measurement of smoothness as applied to printing. This has been called *printing smoothness.* Since that time, The Institute of Paper Chemistry and the West Virginia Pulp & Paper Co. have refined the method further. In the papers which are to follow this one, G. R. Sears and D. N. Obenshain, the representatives of those two organizations, respectively, will disclose their improvements and will present some of the results they have obtained.

In this, the first of the three papers, the author has been asked to present the theory of the method. This was given in detail in the original paper (*10*). Nevertheless, since many are probably not now familiar with it this paper begins with a brief résumé of that earlier one. Then it describes improvements which the Institute in Montreal has made in the original instrument since that earlier publication. Rather extensive studies of the effects of instrumental variables have also been carried out in Montreal, but they will not be reported herein because the paper by Mr. Sears will describe results of his experiments which, it has been found, give a close and independent corroboration to those obtained in Canada several years ago but never published.*

PRINTING SMOOTHNESS

The instrument described in this paper was designed to measure what the Institute has termed "printing smoothness." As is well known, during printing the paper is pressed against the inked form with a pressure of several hundred pounds per square inch. Since paper is a compressible material, it tends to become smoother under this pressure. This being so, it will be evident that a measure of the free surface smoothness, or the smoothness under low pressure, will mean little unless the compressibility is taken into account. This fact was realized by Larocque (*3*) who combined a low-pressure smoothness determination with a softness measurement and found that the result gave a better correlation with the printed result than was obtainable from the low-pressure smoothness measurement alone. It seemed that it should be possible, and preferable, to make the smoothness test at high pressure and thus avoid the need to correct for compressibility. The Canadian Institute therefore defined "printing smoothness" as the fraction of the paper surface which can be brought into contact with a smooth surface under pressures compa-

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* Instrumental variables studied by both Institutes with nearly identical results included: photometric linearity, effect of lamp voltage, effect of the refractive index of the liquid used in calibration, reproducibility, and the effect of time of pressure application.

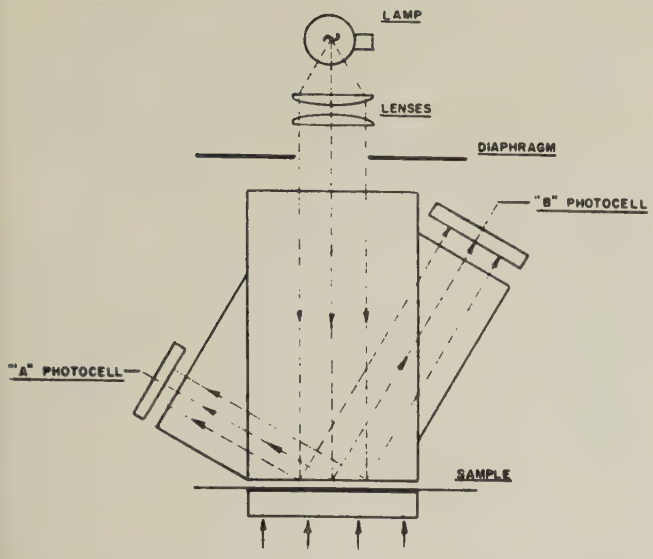

Fig. 1. Optical parts of printing smoothness tester

rable to printing pressures. This is the property which the instrument under consideration attempts to measure.

PRINCIPLE OF THE METHOD

The apparatus consists of a glass prism of special design against which the sample is pressed by means of a small hydraulic press. A parallel beam of light traverses the prism in a direction normal to the sample (see Fig. 1). On reaching the paper this light is partly absorbed and partly reflected back toward the prism. Its subsequent behavior is then dependent on whether or not the paper is in optical contact with the prism. On re-entering the glass, the rays of light will behave in accordance with the usual laws of refraction. The glass of the prism has a refractive index of 1.52; paper has an index fairly close to this same value, but air has, of course, an index of 1.00. It will be obvious that those light rays entering the glass from paper areas in contact with the prism will be bent very little, if at all. On the other hand, those rays which arise at noncontact areas must pass through an air film before entering the glass of the prism. Consequently, they enter the glass from an air medium and are then bent toward the normal in accordance with Snell's Law. It can be shown that the rays which enter the glass from *noncontact* areas will be confined to a cone of about 41° from the normal (see Fig. 2).

This angle will tend to vary very slightly with the color of the light, but it is otherwise very critical. Any rays *outside* this cone could *not* have entered the glass from an air medium. All such rays must, therefore, have originated in *contact areas*. A sample of the light taken from outside the critical cone angle can thus provide a measure of the area of contact. The light flux in a given solid angle will be proportional to the area of contact and also to the reflectance. A similar sample of light taken from within the critical cone angle will contain light from both contact and noncontact areas. Thus, light measurements from both within and without the 41° cone can provide two equations containing reflectance and fractional contact area, from which the latter can be calculated. This quantity is, by definition, the printing smoothness of the sample. The derivation of the equation used was given in the original paper (*10*) so it will not be repeated here. It will suffice to say that the final relationship showed that

$$F = \frac{MA}{B + NA} \qquad (1)$$

where F is the fractional contact area or printing smoothness; A is the current from a photocell arranged to pick up light from *outside* the critical 41° cone (this will hereafter be referred to as the A cell); B is the current from a photocell arranged to pick up light from *within* the critical 41° cone (this cell will hereafter be referred to as the B cell); and M and N are constants.

APPARATUS

As shown in the schematic drawing (Fig. 1), the prism has faces at 30° and 60° to the normal. These provide for obtaining samples of light at these angles and they are obviously well within and without, respectively, the critical 41° cone. A third prism face (not shown) at 45° to the normal allows for visual inspection of the surface of the paper under pressure. Slight movement of the eye allows the observer to see either contact areas only or both contact and noncontact areas at once.

In the original instrument as shown in Figs. 1 and 3, the light was measured by means of barrier-layer photocells cemented to the appropriate prism faces. The cell currents were determined with a galvanometer which could be switched to either cell. The result was then calculated by means of equation (1) given above.

The constants M and N are obtained with the aid of a white glass standard, the surface of which is ground flat with a matte finish. When separated slightly from the prism, this provides a standard of zero contact. Moistening with a suitable fluid (e.g., white oil) and then bringing into contact with the prism provides a standard of 100% contact since the fluid fills in small irregularities in the surface and provides optical contact with the prism. A and B cell readings at both zero and 100% contact provide the information required to calculate the constants M and N from the following equations:

$$M = B'/A'' \qquad (2)$$

$$N = (B' - B'')/A'' \qquad (3)$$

in which A'' is the reading of the A cell at 100% contact; B' is the reading of the B cell at zero contact; and B'' is the reading of the B cell at 100% contact.

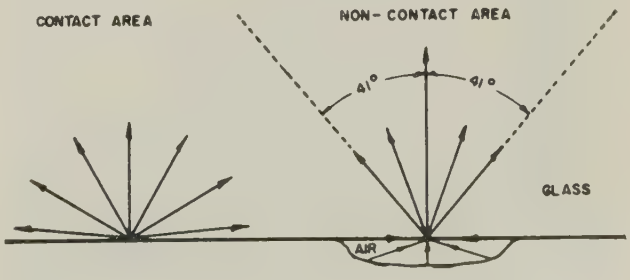

Fig. 2

In this original instrument the cells were found to pick up a certain amount of scattered light from within the prism and attempts were made to correct for this. The Institute of Paper Chemistry (*11*) improved the optical system by providing lenses between the prism and the photocells so as to define more closely the cells' angle of view. This was found to decrease the amount of scattered light received by the cells. This improvement will be described in Mr. Sears' paper.

In the Pulp and Paper Research Institute's first paper on this subject (*10*) it was shown that this type of smoothness increases with pressure, as would be expected. It increases very rapidly with increasing relative humidity, probably as a result of the increased softness at higher moisture contents. The agreement with printing tests on newsprint samples was found to be better than was obtained with the Bekk method. The reproducibility was shown to be excellent but the spread of values found in one class of paper was found to be small.

THEORETICAL CRITICISM OF THE METHOD

There are, admittedly, several theoretical shortcomings to this method that should not be forgotten. They are:

1. The compensation for variations in reflectance of different samples depends upon the assumption that the reflectance at 30° to the normal is proportional to the reflectance at 60°. This is not always the case; but it is believed that the error introduced when comparing papers of similar type is not great. It seems impossible to avoid this error since one cannot measure the reflectance at the same angle as is used for the smoothness determination. To do so would merely duplicate the same measurement. The measurement cannot be made separate from the prism because it must be made under pressure. Reflectance will vary with pressure.

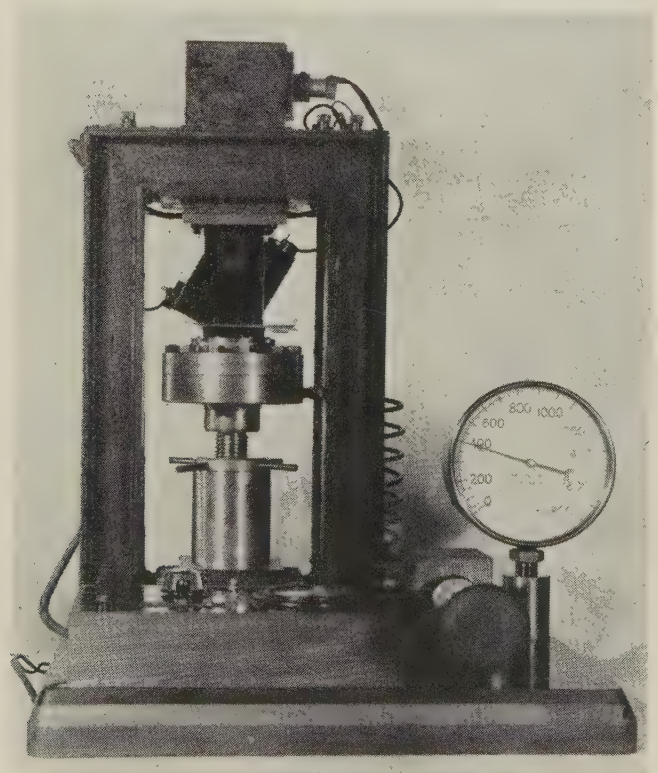

Fig. 3. Original instrument

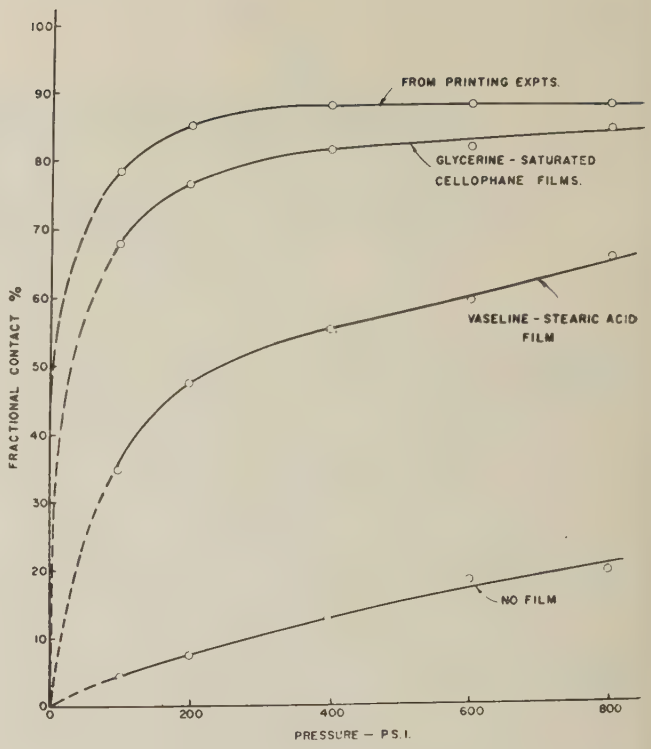

Fig. 4. Effect of pressure on per cent contact

2. The smoothness determination is now made under static pressure conditions. In printing, on the other hand, the paper is nearly always subjected to dynamic pressure. Since paper is a plastic material which takes time to flow under stress, the smoothness will undoubtedly be different under the two sets of conditions. The instrument could probably be redesigned to make it dynamic, but the writer believes that to do so would result in an instrument too expensive and too complicated for any but research purposes. In an attempt to standardize the time of flow the readings are made at 1 min. after the application of pressure to the sample.

3. The present instrument is believed to measure the fraction of the paper area which can be brought into optical contact with the prism. This means that the surface must approach the prism to within a fraction of the wavelength of light (or a distance of the order of a microinch) in order to register as contact. It does not take into account the extremely small depressions which just miss optical contact. In printing, on the other hand, the surface must only approach the printing form within the thickness of the ink film—a matter of 0.0001 or 0.0002 in. This fluid ink film, under the printing pressure, can reach down and fill in very small surface irregularities.

In the case of most papers it may well be that the amount of surface which lies within 0.0001 in. of contact will be proportional to the fraction which lies within a microinch. If this be so, then this source of error will not affect the ranking of samples, although it has a very large effect on the numerical result.

ATTEMPTS TO SIMULATE ACTION OF THE INK FILM

With further reference to this last source of error, attempts have been made to improve the measurement by interposing between the sample and the prism soft, transparent plastic materials so as to simulate the

action of the ink film in printing. As a check on the results obtained with these films, attempts were made to estimate the actual amount of contact in printing experiments, as described in the following section.

ESTIMATES OF THE AMOUNT OF CONTACT IN PRINTING

A series of newsprint prints were made on a Vandercook proof press at various pressures using a solid printing plate. The amount of ink on the plate was held constant at 3.1 grams per square meter, plus or minus 0.1 gram. This was checked by weighing the plate before and after inking. Pressures were varied by changing the thickness of cylinder packing and were estimated by a method similar to that described by Fairbrother and Croney (*13*) in which a pressure-sensitive electrical element was placed in the plate.

The resulting prints were tested for reflectance of both printed and unprinted areas using a Photovolt reflection meter. Knowing the reflectance of the paper, the reflectance of the ink (determined from a very thick film), and the reflectance of the print, it is then possible to calculate approximately the fraction of the paper surface covered by ink from the relation:

$$\% \text{ Contact} = \frac{100(Rs - Rp)}{(Rs - Ri)} \qquad (4)$$

where Rs is the reflectance of the unprinted paper; Rp is the reflectance of the print; and Ri is the reflectance of the ink. This method is subject to some error due to the assumption that the uninked areas have the same reflectance as the unprinted paper whereas the absorption of the printing ink vehicle into these areas will lead to some drop in their reflectance. For this reason all the contact figures so calculated will probably be slightly too high.

The same newsprint was tested for printing smoothness at various pressures using the films between the prism and the sample. These films were attached to the lower prism surface with oil so as to obtain good optical contact with the prism. Fresh film and fresh samples were used for each test. In all cases the sample was underlaid with four additional sheets of the same paper to simulate the effect of the cylinder packing in printing. The smoothness tester was calibrated with the film in place.

A large number of different film materials was tried, including cellophane, polythene, gelatin, collodion, thin sheet rubber, glycerin-saturated cellophane, mixtures of vaseline-stearic acid printed on cellophane as a carrier, and others. All of these proved to be unsatisfactory for various reasons including nonuniformity, insufficient transparency, insufficient softness, too great thickness, or difficulty in handling.

Table I shows some of the results obtained with a few of these films. These results are also illustrated in Fig. 4.

Table I

Pressure, p.s.i.	*Fractional contact, %*			
	From reflectance of prints	*No film*	*Glycerin-saturated cellophane*	*Vaseline-stearic acid film*
100	78.6	4.3	68.0	34.7
200	85.3	7.5	76.7	47.6
400	87.9	12.9	81.4	55.2
600	88.1	18.2	81.9	59.6
800	88.5	19.4	84.8	66.1

It is apparent that the shape of the curves obtained with the use of the films is closer to that obtained from the printing experiments than the results obtained without using such films.

The glycerin-saturated cellophane shows the best result in this connection, but it is felt that this film is both too hard and too thick to be ideal. When attempts were made to correlate results with the printing of different samples it was found that the use of this film gave much poorer correlations than the use of no film at all. The writer believes that the excessive thickness of this film leads to bottoming of large area depressions which are too deep to be reached by the ink film, while its excessive hardness leads to bridging of small area depressions which would be reached by the more fluid ink films. The evaluation of the usefulness of such films by correlating the smoothness data with printing experiments must be done with samples which are of closely similar characteristics because only in such cases will the usefulness of the films become evident. Papers of substantially different surfaces are readily differentiated by the unmodified smoothness measurement. During such tests any variations in relative humidity or temperature can lead to errors greater than the differences one is attempting to discover. Further work along these lines has therefore been postponed until the Institute has adequate control of these atmospheric variables.

The evidence so far suggests that none of the films tried by the writer leads to improvement sufficient to warrant the complications inherent in their use.

RECENT MODIFICATIONS

The original instrument has now been modified by the following changes and additions:

1. Lenses have been installed between the prism and the photocells, as suggested by The Institute of Paper Chemistry (*11*).

2. Diaphragms are positioned immediately in front of the photocells. These are so arranged that an image of the area under test is in focus at each diaphragm. This area is slightly smaller than the area covered by the incident light. They confine the area viewed so that each cell sees exactly the same area of sample. This has been found to reduce the amount of scattered light picked up to negligible amounts so that no correction for this is now required.

3. The barrier layer photocells have been replaced by vacuum cells (type 929) which have the advantages of negligible drift, better stability, and better linearity of response.

4. The lower sensitivity of the vacuum photocells necessitated a more sensitive measuring device than the galvanometer used previously. A simple, balanced d.c. amplifier was first substituted for the galvanometer; but this was then redesigned so as to make the instrument direct reading in terms of per cent contact, thus eliminating the calculations which had to be made previously.

5. The optical parts of the instrument have been enclosed so as to prevent the entrance of external illumination. An observation port is provided which can be covered when not in use.

MEASUREMENT CIRCUIT

The redesigned instrument built by Mr. Obenshain (*12*), which he will describe in detail in his paper, was the first of these smoothness testers to be made direct reading and his method appears to be superior to the method now used at the Canadian Institute. Nevertheless, the apparatus we have is relatively simple and the author would like to describe it for record purposes.

The original equation can be rearranged to the form:

$$F = \frac{M(A/B)}{1 + N(A/B)} \qquad (5)$$

It will be seen that this provides a relation between the smoothness F and the ratio of the cell currents A/B. If this ratio can be made direct reading, then the scale of the instrument can be recalibrated in terms of smoothness.

If the B cell reading can be kept numerically constant, then the ratio A/B will be proportional to the A cell reading and the latter can then be calibrated in terms of smoothness. This can be done by any method which will vary both cell readings in proportion. Thus the B cell reading can be set to a fixed value and the A cell reading will be changed proportionally and will be then a function of smoothness. The simplest and most obvious way to do this would be to install an iris diaphragm at the light source so as to be able to vary the light intensity in the prism without changing its color temperature. This method was not mechanically convenient in the case of our instrument although it would be quite simple if an entirely new instrument were to be constructed. We achieved essentially the same effect by providing a shunt potentiometer across the output meter of the d.c. amplifier.

Figures 5 and 6 illustrate the wiring diagram and the completed instrument, respectively. Referring to Fig. 5, it will be seen that the circuit consists of a 6SN7GT tube with its two triode sections connected as a balanced d.c. vacuum-tube voltmeter. The shunt potentiometer across the meter can vary the sensitivity of the measurement. This vacuum-tube voltmeter measures the voltage across resistors through which the photoelectric current flows. A switch is provided

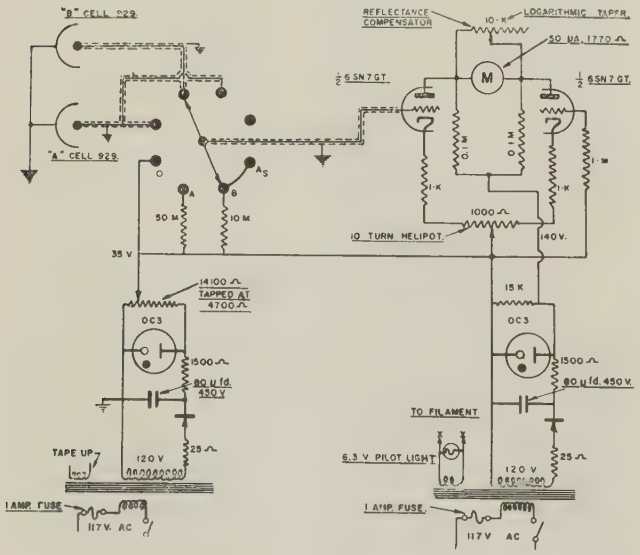

Fig. 5. Revised wiring diagram for printing smoothness tester

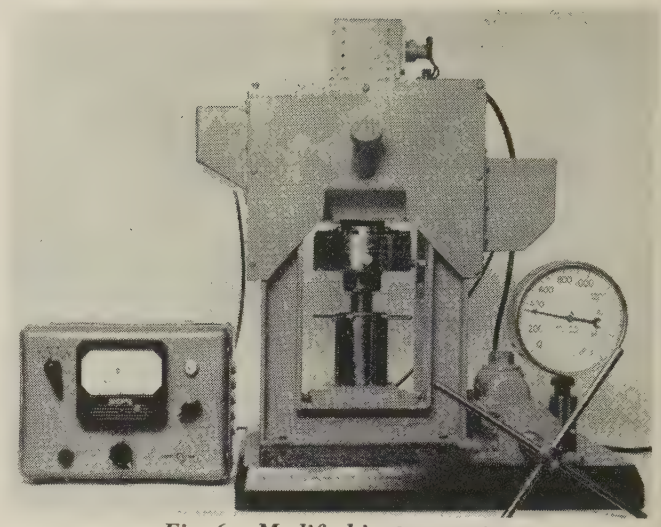

Fig. 6. Modified instrument

having four positions marked 0, A, B, and A_s, respectively. These have the following functions:

Position O is used to balance the vacuum-tube voltmeter to read zero with no input. This is done by means of the 1000-ohm helipot. Position A provides a measurement of the A cell current. Position B provides a measurement of the B cell current; and finally, position A_s is the same as position A but has a sensitivity one fifth of that in the A setting. The scale of the microammeter is calibrated in terms of per cent contact, two scales being provided, zero to 30% contact (switch position A) and zero to 100% contact (switch position A_s).

An adjustable index is mounted on the scale of the microammeter to mark the point on the scale to which the B cell reading is set each time in order that the instrument may read correctly in terms of smoothness when the switch is turned from the B position to either the A or A_s position. This adjustment provides for standardization of the instrument. It can be shown (see Appendix) that selection of the B cell reading so as to make the instrument read correctly on the standard will compensate for any variations in the cells, dirt in the optical system (except on the bottom surface of the prism), or variations in the sensitivity of the amplifier. It is only necessary that the amplifier remain linear in its response and that the solid angles of light viewed by the cells remain constant.

METHOD OF OPERATION

Standardization

1. Turn on the instrument and allow it to warm up for about 20 min.
2. With the balance control set the zero of the meter. The function switch should be in the O position.
3. Lower the hydraulic press section away from the prism by means of the capstan screw.
4. Clean the bottom surface of the prism with lens tissue.
5. Moisten the surface of the white glass standard with oil and insert it between the prism and the hydraulic press, bringing the press up so as to touch the standard to the prism. Only hand pressure should be used.
6. Check the contact visually through the inspection port to be sure that there are no bubbles present and that the contact seems to be perfect.

7. Move the function switch to A_s position.

8. Adjust the reflectance compensation control until the instrument reads correctly at 100% contact.

9. Move the function switch to the B position and set the adjustable scale index to the meter reading.

The instrument is then on calibration. This setting does not change appreciably over a week or so but it should be checked at least once a day.

Making a Smoothness Determination

1. Set the calibration against the standard as described in the preceding section.

2. Clean the bottom surface of the prism with carbon tetrachloride and lens tissue.

3. Lower the hydraulic press and insert the sample and backing material.

4. Raise the press until the sample is pressed against the prism.

5. Increase the pressure to the desired value with the hydraulic pump.

6. Set the function switch to the B position.

7. Adjust the reflectance compensation control until the meter reads the value set by the scale index.

8. Turn the switch to the A or A_s position, depending on the magnitude of the reading, and read off the per cent contact, or printing smoothness. This final reading should be taken 1 min. after the initial application of pressure to the sample.

CONCLUSION

Use of this method of determining printing smoothness by the Pulp and Paper Research Institute of Canada for the past 6 years has shown the method to be useful and generally reliable. Recent modifications which eliminate the necessity of calculating the results have led to more rapid operation and the elimination of arithmetical errors. The method has been found to have the following advantages: (1) it is rapid and used easily by untrained personnel; (2) the reproducibility is good; (3) it correlates with printed results better than any other method the writer has investigated; (4) the possibility of examining the surface contact under pressure visually has proved to be a valuable feature. One can frequently see defects that do not reveal themselves in any measurement of the surface.

APPENDIX

Proof of Independence of Instrument of Changing Cell Sensitivities, Dirt in the Optical System, etc.

The basic formula from which the result is calculated is given by equation (5)

$$F = \frac{M(A/B)}{1 + N(A/B)}$$

where F is the fractional contact area or printing smoothness; A is the A cell reading; B is the B cell reading; and M and N are constants.

In the original calibration of the instrument, the constants M and N are obtained from equations (2) and (3)

$$M = B'/A'' \text{ and } N = (B' - B'')/A''$$

where B' is the reading of the B cell on the standard at zero contact; B'' is the reading of the B cell on the standard at 100% contact; and A'' is the reading of the A cell on the standard at 100% contact. The A scale is then calibrated in terms of per cent contact for a constant B cell reading which we will call B.

In the operation of restandardizing the instrument it is assumed that the standard has not changed in any way and that the position of the various parts of the optical system has not been changed. The *over-all* sensitivity of the A side of the instrument is brought to the original value by setting the instrument to read correctly at 100 on the standard at 100% contact. This is done by means of the shunt potentiometer across the output meter. It will be obvious that this procedure will correct this side of the instrument for any changes in cell sensitivity, changes in optical transmission due to dirt (except on the bottom of the prism), variations in amplifier sensitivity, or aging of the lamp. If, for any of these reasons the *over-all* sensitivity of this side of the instrument had changed by a factor Δ_A, then one will have corrected for the change by changing the sensitivity of the output meter by a factor $1/\Delta_A$.

This adjustment leads, of course, to a similar change in the *over-all* sensitivity of the B side of the instrument; and if this side had changed independently by a factor Δ_B for any of the same reasons, then the resulting *over-all* sensitivity of the B side will be the original sensitivity multiplied by a factor Δ_B/Δ_A.

Under these new conditions of A and B over-all sensitivities, the new instrument constants, M' and N' will obviously be given by

$$M' = M(\Delta_B/\Delta_A) \text{ and } N' = N(\Delta_B/\Delta_A)$$

since the over-all sensitivity of the A side has been restored to its original value. And the basic formula becomes:

$$F = \frac{M'/(A/B)}{1 + N'(A/B)} = \frac{M(\Delta_B/\Delta_A)\left[\dfrac{A}{B(\Delta_B/\Delta_A)}\right]}{1 + N(\Delta_B/\Delta_A)\left[\dfrac{A}{B(\Delta_B/\Delta_A)}\right]} = \frac{M(A/B)}{1 + N(A/B)}$$

the original equation for which the scale was calibrated. Thus, by changing the B setting from B to $B(\Delta_B/\Delta_A)$ by this procedure one automatically changes the constants so as to correct for any variations which may have taken place in over-all sensitivity of either side and the scale calibration will remain unchanged as long as the amplifier remains linear.

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The Chapman Printing Smoothness Tester

II. Instrument Variables and Some Results of Application

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A modified Chapman printing smoothness tester is described. The results of study of some of the instrument variables are given. The dependence of printing smoothness upon pressure is illustrated for a number of papers backed by hard and soft materials. The patterns of contact areas vary greatly among papers and illustrations of this variation are presented. The smoothness values of a number of rubber sheets and offset press blankets are given.

A generally recognized member of the group of properties which determine the printability of paper is the smoothness of the surface when under pressure, the so-called printing smoothness. Following Chapman's description (*1*) of a printing smoothness tester, it was of interest to study the application of his instrument to the study of printing papers. Mr. Chapman kindly provided blueprints of the working drawings of the smoothness tester and an instrument was constructed at The Institute of Paper Chemistry, without significant modifications. Early in the study of the instrument it became desirable to modify the optical system. This paper describes the modification, presents the results of a study of the instrument variables, and discusses some of the results of the testing of printing papers.

The procedure used in calibrating the instrument and the equations for instrument constants and printing smoothness values were those described by Chapman (*1*). For convenience, the symbols and equations are listed below.

A' = Photocell A reading, zero contact with glass standard
B' = Photocell B reading, zero contact with glass standard
A'' = Photocell A reading, oil (100%) contact with glass standard
B'' = Photocell B reading, oil (100%) contact with glass standard
A = Photocell A reading, test specimen
B = Photocell B reading, test specimen

$$\text{Instrument constants} \quad M = B'/A'' \qquad N = (B' - B'')/A''$$

$$\text{Chapman printing smoothness} = F = M/(N + B/A)$$

This last equation yields F as a fraction. It is convenient to express F as a percentage and throughout this paper percentage units are used.

The smoothness data reported here were obtained for papers conditioned and tested at 73°F. and 50% R.H.

MODIFICATION OF THE OPTICAL SYSTEM OF THE CHAPMAN PRINTING SMOOTHNESS TESTER

A photograph of the Chapman instrument at The Institute of Paper Chemistry is presented in Fig. 1. Its similarity to Chapman's original instrument is apparent. The modification of the optical system, which constitutes the only significant deviation from Chapman's design, is shown schematically in Fig. 2.

In Chapman's original instrument, photocells A and B were placed directly in contact with the corresponding prisms A and B. It seemed that this arrangement might not adequately discriminate between the desired reflected rays and light rays which may be classified as "scattered" and exist because of the various imperfections in the optical system. The new optical components were added to make the effects of stray radiation very slight and to ensure the arrival at photocells A and B of rays originating almost exclusively in a well-defined zone of the illuminated portion of the specimen. The lenses A image the selected area of the specimen on the window of photocell A through a suitable aperture in a diaphragm cemented to the window. The lens B images the same specimen area on the window of photocell B. Limitations of space required the use of the right-angle prism to change the direction of the reflected rays through prism B by 90°. The details of the lens mountings are shown in the drawings of Figs. 3 and 4.

The effect of this modification of the instrument by addition of these optical components is illustrated by calibration data obtained before and after the modification. Three different opal glass blocks were used, and the calibration procedure described by Chapman was followed. The surfaces of the blocks were lightly ground with no. 600 carborundum. Before modification, calibration data were obtained with a 1 by $^3/_4$-in. aperture in the black paper mask over each photocell window and also with a 1 by $^7/_{16}$-in. aperture. The data are presented in Table I. After modification, calibration data were obtained with the same opal glass blocks. These data are shown in Table I.

When F is zero, the current of photocell A should be zero, i.e., A' should be zero. It is apparent from Table I that this was not actually the case, either before or after modification of the optical system. The photocurrent corresponding to galvanometer deflection A' is a measure of the scattered light in the system for zero area of optical contact. The ratios A'/B' and A'/A'' are less and, hence, the influence of scattered light is less with the modified system.

The instrument constants M and N should be nearly the same for all the opal glass standards. The values of M and N in Table I are not constant either before or after the modification of the optical system. The

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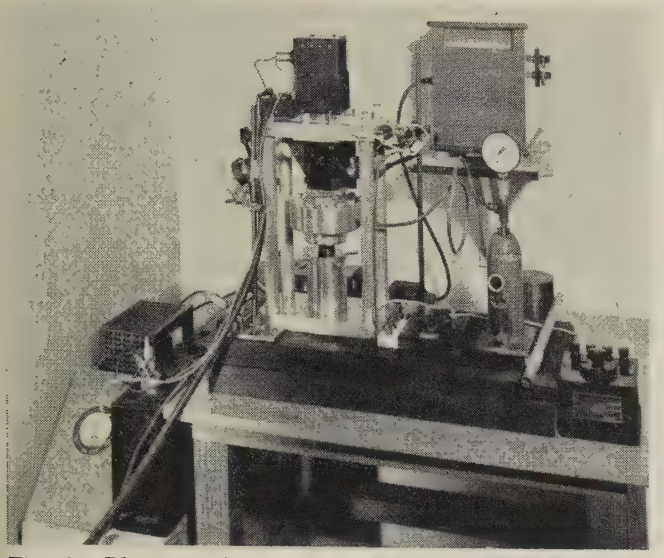


Fig. 1. Photograph of the modified Chapman printing smoothness tester at The Institute of Paper Chemistry

spread in values for the modified system is less than for the original system with the larger aperture and is about the same as for the original system with the smaller aperture.

It is believed that differences in the angular distribution of the light reflected by the several glass blocks are the principal cause of the variation of the instrument constants. As additional illustrations of the effect of modification of the optical system, the Chapman printing smoothness values (F-values) of several papers were obtained with the original and with the modified system at each of six pressures. Each specimen was backed by four similar specimens and the specimen was tested at each pressure, progressing from the lowest to the highest pressure. The A galvanometer reading was made 20 sec. after application of each pressure and the B reading was made as soon thereafter as possible. The smoothness values are presented in Table II.

It is apparent that the use of the modified optical system leads to higher F-values, the percentage increase being greater for the sheets of better finish. This is undoubtedly the result of improved definition of the angles of the light rays accepted by the photocells, of better definition of the viewed area, and minimization of stray light.

All data presented hereafter were obtained with the modified instrument.

Table I. Calibration Data Obtained Before and After Modification of Optical System

Opal glass block	A′	B′	A″	B″	M	N
Before modification, with 1 by 3/4-in. aperture						
1	1.5	99.0	105.3	81.8	0.940	0.163
2	1.6	110.4	105.9	78.0	1.042	0.306
3	1.6	110.4	107.4	80.0	1.028	0.283
Before modification, with 1 by 7/16-in. aperture						
1	0.67	52.2	56.8	43.0	0.919	0.162
2	0.65	52.9	55.9	43.7	0.946	0.165
After modification						
1	1.27	123.3	176.7	77.4	0.698	0.260
2	1.13	120.6	174.0	77.4	0.693	0.248
3	1.11	124.8	171.6	80.7	0.727	0.257

Table II

Sample	*Pressure, p.s.i.*	*Original*	*F-Values, % modified*	*Increase, %*
Newsprint 3, felt side	87	5.0	5.9	19
	175	7.5	8.3	11
	350	11.9	12.9	9
	438	14.6	14.5	−1
	525	15.6	16.0	3
	700	18.0	18.9	5
Newsprint 7, felt side	87	7.2	8.7	20
	175	10.5	12.7	22
	350	16.7	19.0	14
	438	19.2	21.5	12
	525	20.8	23.5	13
	700	24.5	26.5	8
Coated book 59, felt side	87	6.9	10.1	46
	175	11.7	16.0	37
	350	19.9	25.7	29
	438	23.2	30.4	31
	525	26.3	33.9	29
	700	31.1	39.2	26
Coated book 55, felt side	87	11.6	17.3	49
	175	19.2	27.4	43
	350	31.2	42.0	35
	438	36.6	47.6	30
	525	40.5	51.6	27
	700	48.2	58.6	22

LINEARITY OF THE PHOTOMETRIC SYSTEMS

In any photoelectric instrument in which the instrumental reading (galvanometer deflection in this case) is supposed to be directly proportional to the amount of light received by the photocell, it is important that the "linearity" be tested. The linearity of the two photometric systems was tested through the use of three achromatic screens. These metal screens were slightly blackened with camphor soot to minimize errors arising in reflection from the boundaries of the openings, and the transmissions were determined with the General Electric recording spectrophotometer (GERS). An opal glass block was placed in the Chapman instrument with oil applied to produce the full optical contact condition. The apparent transmissions of each of the three screens were then determined in both the A and

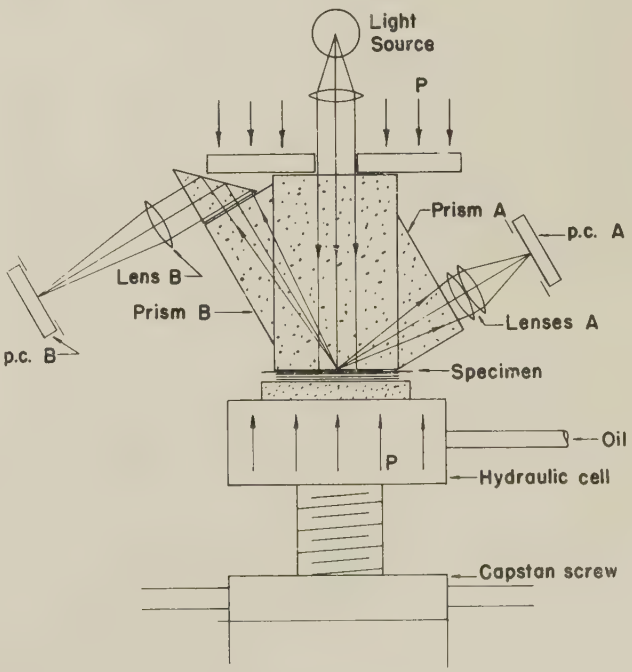


Fig. 2. Schematic diagram of the optical system of the modified Chapman printing smoothness tester

Table III. Data on Linearity of Photometric Systems

Screen	GERS	Transmission, % A System	Transmission, % B System
1	26.1	25.4	26.0
2	40.6	40.3	40.9
3	62.2	61.7	62.4

B photometric systems. This was done by noting the A and B galvanometer deflections before and after insertion of a screen in the incident light beam. The apparent screen transmissions thus observed are compared in Table III with the known transmissions previously obtained with the General Electric recording spectrophotometer.

The indicated deviations from strict linearity are considered to be adequately small for satisfactory behavior of the instrument.

SOME OBSERVATIONS OF THE A' READING FOR ZERO CONTACT

It has been noted that the A' reading is not zero, as it should be. In an effort to learn more about the stray light which must be the cause of this zero contact reading, the following experiments were carried out.

With the room darkened, the capstan screw was turned to lower the opal glass block to its lowest possible position (about 0.8 in. below the main prism). Then the screw was slowly turned to raise the opal glass block toward the prism. It was observed that the A' reading increased, reached a maximum value, decreased, and reached a minimum value just as the opal glass touched the prism. The B' reading increased continuously during this maneuver. This experiment was repeated with a black velour paper and with a newsprint replacing the opal glass and the same phenomena were observed, except that the readings with the black velour paper were of a lower order of magnitude. The maximum and minimum values of A' and the values of A' at the lowest specimen position are given in Table IV.

Consideration of the geometry of the optical system shows that a maximum value of A' might be expected. Dust, fibers, and scratches on the bottom surface of the prism scatter light into the prism at angles with the vertical greater than the critical angle of 41° and some of this light reaches the A photocell. The illumination of some of these particles and scratches (particularly those outside of the central zone) would be increased somewhat by lowering the specimen from its "just out of contact" position and this would result in an increase in A'. Furthermore, light entering the prism within the critical angle may be multiply reflected from the

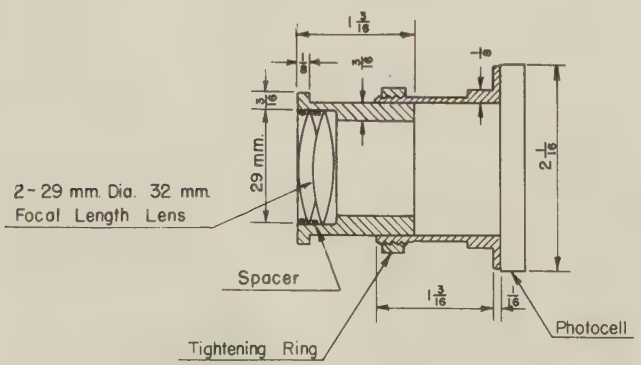


Fig. 3. Lens mounting for prism A

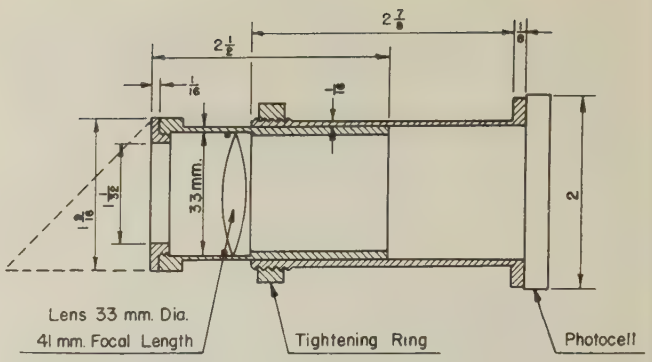


Fig. 4. Lens mounting for prism B

boundary surfaces of the optical system and some of the stray rays would be intensified by lowering the specimen.

Additiona' experiments with diffuse and specular reflectors placed under the prism confirmed the suspicion that most of the stray light originated at debris and surface imperfections on the bottom face of the prism.

The value of A' must be kept small by frequent and thorough cleaning of the prism. Undoubtedly, after extended use it will become necessary to repolish the bottom face of the prism.

Consideration was given the matter of correcting the instrument readings for stray light. One procedure would be to subtract A' from A'' in the standardization, thus determining the instrument constants as $M = B'/(A'' - A')$ and $N = (B' - B'')/(A'' - A')$, and to subtract A' from A in calculating an F-value as: $F = M/[N + B/(A - A')]$. On the other hand, it might be argued that the correction should be $A'(1 - F)$, because $(1 - F)$ is the fraction of the area in which stray light may originate in the illuminated portion of the prism face. When A' is used as the correction term, the instrument constants M and N are about 1% higher than when no correction is made. As the stray light error seems to be small except for specimens of small F-values and low reflectance, it has been our practice to make no correction to A' or A.

EFFECT OF LAMP VOLTAGE

Although the voltage applied to the lamp should be carefully controlled at a constant value, it was considered desirable to explore the effects of changing the lamp voltage. A single opal glass standard was used to calibrate the instrument with various lamp voltages between 4.18 and 5.88. The data thus obtained are presented in Table V. They show that there is little dependence of the instrument constants M and N on the lamp voltage.

The dependence on lamp voltage of the F-values of a newsprint was tested by placing a specimen in the instrument, applying a constant low pressure, and taking the galvanometer readings at various lamp volt-

Table IV. Effect of Specimen Position of A' Reading

Specimen	A', galvanometer deflection in mm. Lowest specimen position	Maximum	Minimum
Opal glass	7.5	19.29	1.8
Newsprint	3.96	14.64	2.1
Black velour paper	0.27	0.42	0.22

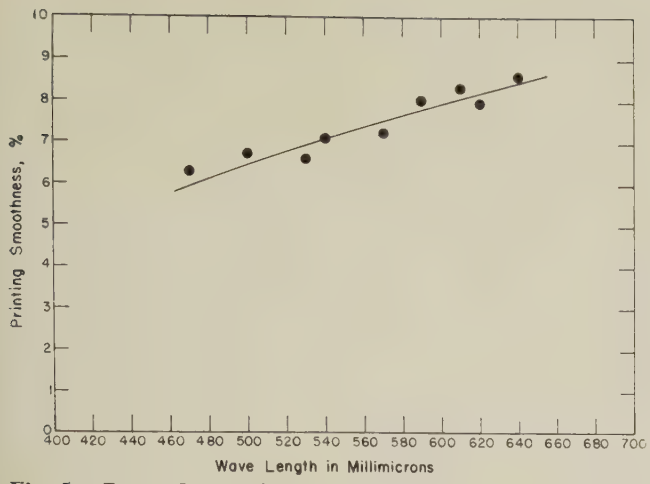


Fig. 5. Dependence of the F-value for a paper on the effective wavelength of the incident light

ages. The results are presented in Table VI. They show that there was no substantial effect of lamp voltage on the *F*-values. The average instrument constants from Table V were used in the calculations.

EFFECT OF THE LIQUID USED IN THE CALIBRATION PROCEDURE

It will be recalled that the standardization procedure involves the use of mineral oil between the opal glass standard and the prism. Although the mineral oil wets both glass surfaces, the contact cannot be described accurately as optical unless the indices of refraction of the three media are identical. The index of refraction of the mineral oil was 1.4770 and was less than that of the glass (1.52). Accordingly, it was felt desirable to make three complete determinations of the instrument constants using mineral oil, chlorobenzene, and aniline. The refractive indices of these liquids were 1.4770, 1.5209, and 1.5829, respectively, and were less than, about equal to, and greater than the index of the glass. The data are presented in Table VII.

It is apparent that significant changes in instrument constants resulted from the change in refractive index from 1.4770 to 1.5829. A specimen of newsprint and a specimen of a coated paper were tested at 100 and 400 p.s.i., respectively, and the *F*-values calculated for each set of instrument constants in Table VII. The results are presented in Table VIII.

These data indicate that the use of mineral oil instead of a liquid of more ideal refractive index results in an error in *F*-value of the order of only 1 or 2%. As the effective refractive indices of paper surfaces (*2*) also differ from the value of 1.52 for the prism, it does not seem necessary to discontinue the use of mineral oil for calibration purposes.

Table V. Instrument Constants for Different Lamp Voltages

Lamp voltage	A′	B′	A″	B″	M	N
5.88	2.15	180.1	203.7	104.6	0.884	0.371
5.75	1.99	165.1	186.0	94.7	0.888	0.378
5.55	1.76	145.0	165.0	85.0	0.879	0.364
5.41	1.60	134.1	153.0	78.7	0.876	0.362
5.38	1.54	129.3	147.0	75.9	0.880	0.363
5.10	1.30	107.7	123.0	63.2	0.876	0.362
4.80	1.04	87.1	99.0	51.0	0.880	0.365
4.48	0.81	69.0	77.6	39.9	0.889	0.375
4.18	0.61	52.2	60.1	31.0	0.869	0.353
				Average	0.880	0.366

Table VI. *F*-Values of a Newsprint at Different Lamp Voltages

Lamp voltage	A	B	F, %
6.0	18.1	174.0	8.82
5.92	17.2	167.4	8.71
5.78	16.0	153.0	8.86
5.6	14.1	138.0	8.67
5.5	13.3	129.6	8.70
5.3	11.9	114.6	8.80
5.2	10.9	104.7	8.82
5.0	9.7	93.6	8.79

EFFECT OF COLOR

Color, in itself, should have no influence upon the contour of a paper surface under platen pressure. However, one always suspects that an indirect method based on optical principles might yield a result which would depend upon the color of the specimen or the color of the light employed in the instrument.

An ideal experiment for testing the influence of specimen color on the printing smoothness values would involve testing papers which were identical except for color. Such papers are not available. However, this idealized experiment may be simulated simply by changing the color of the incident light. This use of colored light is ideal except for certain stray light effects.

The *F*-values of a coated paper specimen were determined under light pressure (obtained by manual adjustment of the capstan screw) using, successively,

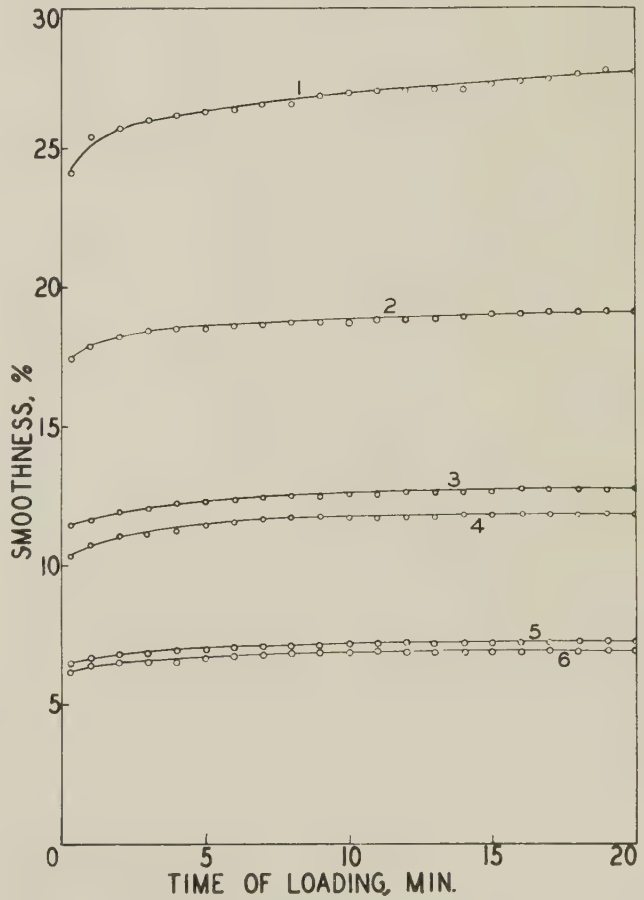


Fig. 6. Change of printing smoothness with time of loading

1—Coated sheet at 708 p.s.i. 2—Newsprint at 708 p.s.i. 3—Newsprint at 354 p.s.i. 4—Coated sheet at 354 p.s.i. 5—Newsprint at 177 p.s.i. 6—Coated sheet at 177 p.s.i.

Table VII. Calibration Data Obtained with Mineral Oil, Chlorobenzene, and Aniline

Liquid	A′	B′	A″	B″	M	N
Mineral oil	1.93	155.9	174.0	89.6	0.896	0.381
Chlorobenzene	1.90	156.1	170.4	88.1	0.916	0.399
Aniline	1.98	156.0	160.5	86.0	0.972	0.436

ten Wratten filters in the incident light beam. The results are given in Table IX.

The second column of Table IX presents rough estimates of the effective wavelengths of the light source, filter, and photocell combination for each filter. The plot of *F*-value versus effective wavelength which is presented in Fig. 5 shows an unmistakable trend for the *F*-values to increase with increasing effective wavelength. This relationship can be understood when it is recalled that the distance between surfaces in "optical contact" is not a sharply definable distance, but is a function of the wavelength of the light. If the wavelength is made smaller, the distance of separation corresponding to optical contact becomes smaller. If one visualizes the probable manner in which an imperfect surface, such as a paper surface, meets the prism face—a trace of the resilient surface would be a sinuous curve alternately winding toward and away from contact with the glass surface—it is readily appreciated that the total area of optical contact should be larger at a greater effective wavelength. The slope of the relationship in Fig. 5 would depend on the way in which the convolutions of the paper surface meet the prism. If the surface were of an improbable kind in which it met and left the prism face suddenly (with sharp-angle bends), one would expect that the *F*-values would be less dependent on the effective wavelength than in the more probable situation in which the paper surface more smoothly winds toward and away from the prism face. In short, the data in Table IX and Fig. 5 are about what one would expect.

The range of effective wavelengths in the foregoing experiment is much greater than that to be expected on

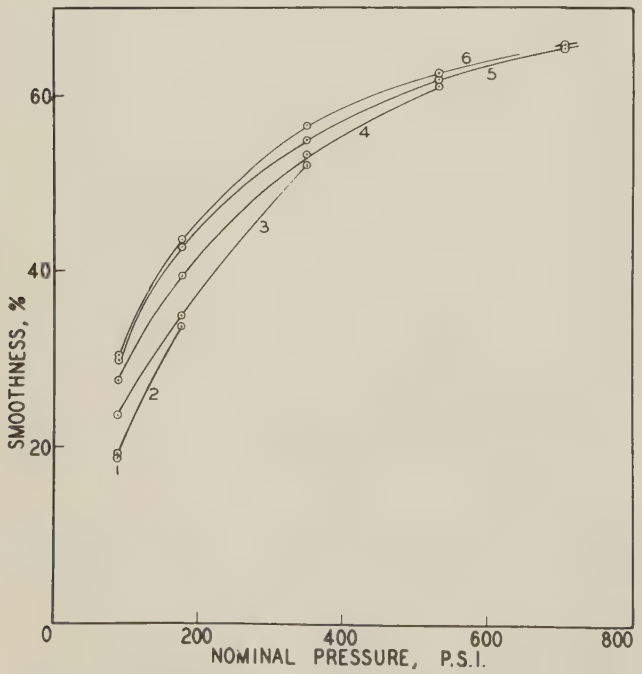


Fig. 7. Dependence of printing smoothness on nominal pressure for a coated paper subjected to repeated loading cycles

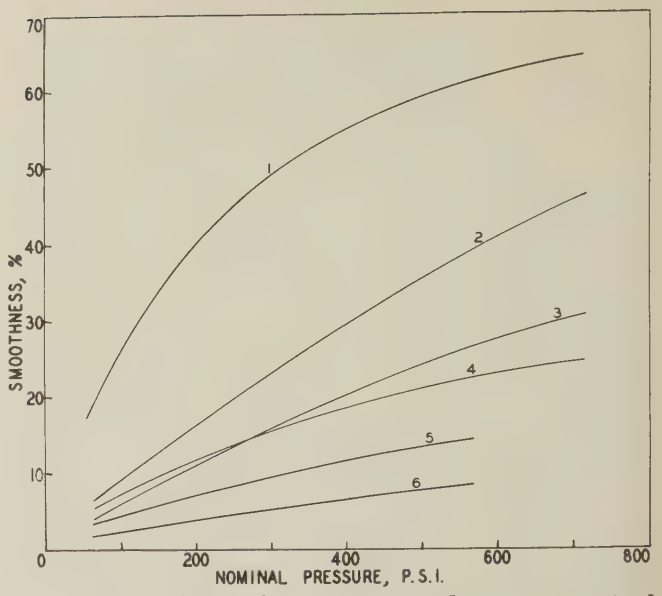


Fig. 8. Dependence of printing smoothness on nominal pressure for a variety of papers; glass backing

1—Cast-coated paper. 2—Coated paper no. 2, felt side. 3—Coated paper no. 3, felt side. 4—Newsprint, typical, felt side. 5—Newsprint, 85% deinked news, wire side. 6—Newsprint, bagasse-filled, wire side.

the basis of variability of color of "white" papers. No serious error in relative smoothness values should result from the variability of color of such papers. However, in comparisons of highly colored papers it should be remembered that all other things being the same, a red sheet would have a higher Chapman printing smoothness than a green or a blue sheet.

STUDY OF VARIABILITY

If the process of testing does not modify a specimen in any manner whatsoever, the "reproducibility" of an instrument may be simply tested by measuring the same specimens repeatedly. The Chapman smoothness test involves the application of substantial pressure to the paper specimen and, as paper displays creep properties, a reproducibility test may not be performed. However, it was thought desirable to perform tests on large numbers of specimens from several samples of newsprint, using, in each set, specimens cut from a single sheet of paper. The variability observed in this type of experiment is a function of the variability of the paper and of the instrument.

Forty-eight specimens of each of three samples of newsprint were tested on the felt sides at pressures of 100 and 400 p.s.i. Each specimen was backed by four fresh specimens cut from the same roll of paper. At 100 p.s.i. the percentage standard deviations were 4.2, 5.6, and 5.5 and at 400 p.s.i. the corresponding values were 2.9, 4.8, and 3.0. In agreement with Chapman's findings (*1*), the combined variabilities of the papers and the instrument are about as small as one could expect on the basis of the known variability of paper.

Table VIII. *F*-Values Corresponding to Instrument Constants in Table VII

Specimen	*Mineral oil*	*F-Values, % chlorobenzene*	*Aniline*
Newsprint	9.55	9.75	10.30
Coated paper	6.82	68.8	71.1

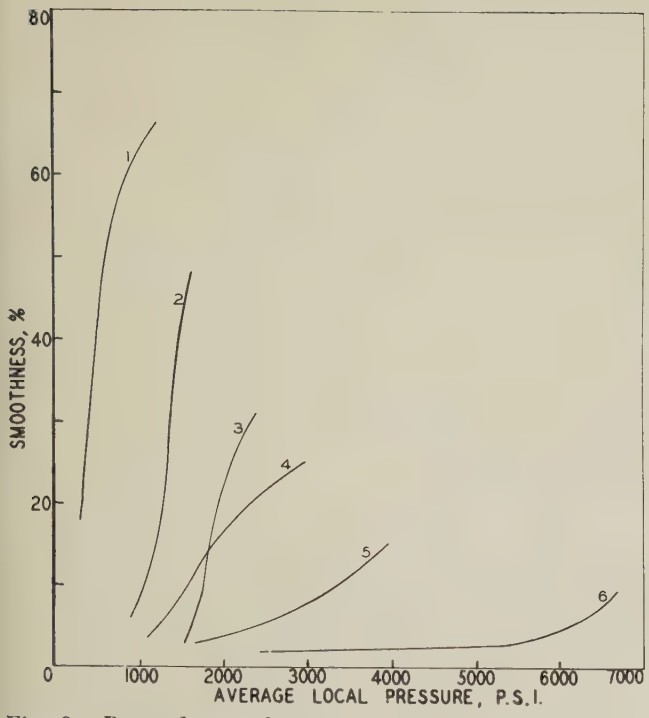


Fig. 9. Dependence of printing smoothness on average local pressure for a variety of papers; glass backing

1—Cast-coated paper. 2—Coated paper no. 2, felt side. 3—Coated paper no. 3, felt side. 4—Newsprint, typical, felt side. 5—Newsprint, 85% deinked news, wire side. 6—Newsprint, bagasse-filled, wire side.

DEPENDENCE OF *F*-VALUES ON TIME OF PRESSURE APPLICATION

During test in the Chapman instrument the paper specimen yields or creeps under continued pressure and the smoothness increases with time of pressure application. It is the A reading that changes with time; the B reading is constant. In order to simulate printing conditions, the pressure should be applied rapidly and the necessary readings (at least the A reading) made within a fraction of a second of the application of pressure. With the present instrument, the A reading is normally made 20 sec. after application of pressure and the B reading is made as shortly thereafter as possible. This interval is, of course, extremely large compared to the time of impression. A few experiments were performed to illustrate the change in smoothness with time of loading. A specimen of a newsprint was placed in the instrument, backed by a glass plate, a pressure of 177 p.s.i. was applied and maintained, and galvanometer deflections read at intervals during a 20-min. period. The process was repeated with other specimens of the same newsprint at pressures of 354 and 708 p.s.i. A coated sheet was treated likewise. The smoothness values are shown as a function of time of loading in Fig. 6. In the case of the newsprint, the smoothness at first rises with increasing loading time and then levels out to a constant value. The smoothness of the coated sheet does likewise at the lower pressures, but at the highest pressure the smoothness is still rising 20 min. after application of pressure. The percentage smoothness increments during the interval from 20 sec. to 20 min. were 12.3, 11.8, and 9.1 for the newsprint and 14.7, 14.5, and 15.3 for the coated sheet at the pressures of 177, 354, and 708 p.s.i., respectively. It is not appropriate to extrapolate and attempt to estimate the smoothness changes between the fraction of a second characteristic of printing impressions and 20 sec.

When smoothness values are determined at several pressures, it has been our practice to test each specimen at each of the series of pressures, beginning at the lowest and progressing to the highest pressure. At each pressure, the A reading is made 20 sec. after application of the pressure, the B reading is made, the pressure is raised to the next value, and these steps are repeated. We have found that the smoothness value at a given pressure is not significantly affected by the preceding tests in the series when the steps in pressure are of the order of 100 p.s.i. However, the smoothness at a given pressure is higher after an excursion to a higher pressure.

Table IX. *F*-Values of a Coated Paper with Color Filters in the Incident Light Beam

Wratten filter	*Estimated effective wavelength, mmu*	F, %
None	570	7.24
44A	470	6.31
65	500	6.75
58	530	6.61
56	540	7.10
15	590	7.98
30	590	8.02
22	610	8.31
32	620	7.95
26	640	8.58
88	> 700	8.60

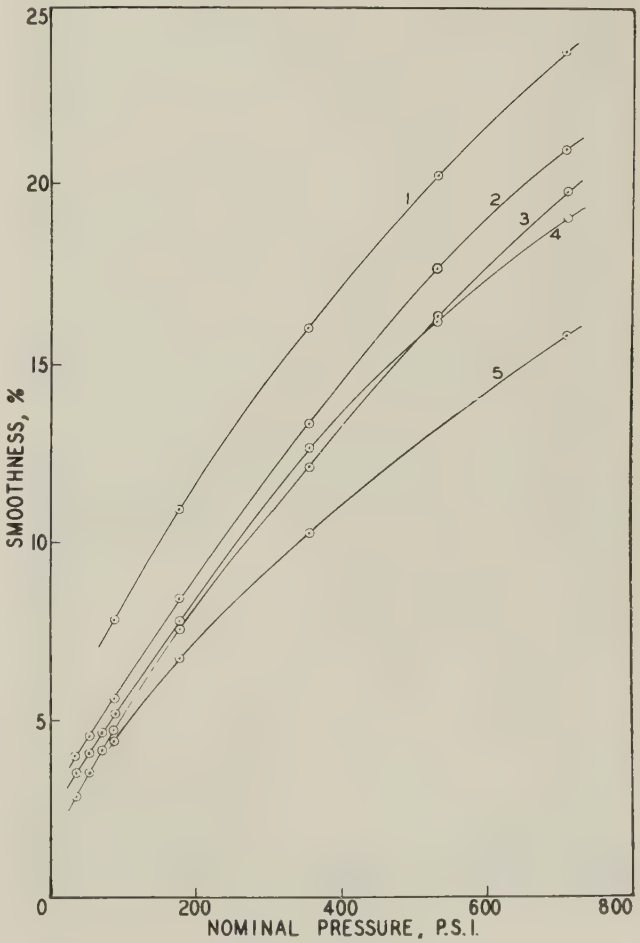


Fig. 10. Dependence of printing smoothness on nominal pressure for a newsprint backed by different materials

1—Silicone rubber. 2—Offset press blanket. 3—News press blanket. 4—Glass. 5—Index card stock.

The behavior is illustrated in Fig. 7, in which are plotted the smoothness values for a specimen of coated paper when subjected to repeated cycles of loading. The specimen was placed in the instrument and backed by a glass plate. The first cycle consisted in raising the pressure to 88 p.s.i. and relieving the pressure. In the second cycle, the pressure was raised to 88 p.s.i., then to 177 p.s.i., and then relieved. The third cycle consisted in steps of 88, 177, and 354 p.s.i., and relief; the fourth, in steps of 88, 177, 354, and 531 p.s.i., and relief; the fifth in steps of 88, 177, 354, 531, and 708 p.s.i., and relief. The sixth cycle was a repetition of the fifth. Smoothness values were determined at each pressure, other than zero, by the usual procedure. The numbers on the curves of Fig. 7 indicate the cycles.

METHODS OF PRESENTING SMOOTHNESS DATA

The most direct way of presenting smoothness data obtained at a number of pressures is to plot the smoothness values as a function of the nominal pressure. Figure 8 illustrates such a presentation of data for six papers covering a wide range of smoothness characteristics. The specimens were backed by a glass plate for these tests. It is apparent that the papers differ not only in general level of printing smoothness but also in rate of change of smoothness with pressure.

The nominal test pressure is the total force on the specimen divided by the superficial area over which this force is applied. Because only a part of the specimen surface is in contact with the prism face, the actual local pressures on some of the areas of contact between specimen and prism face must be higher than the nominal pressure. These local pressures must vary greatly

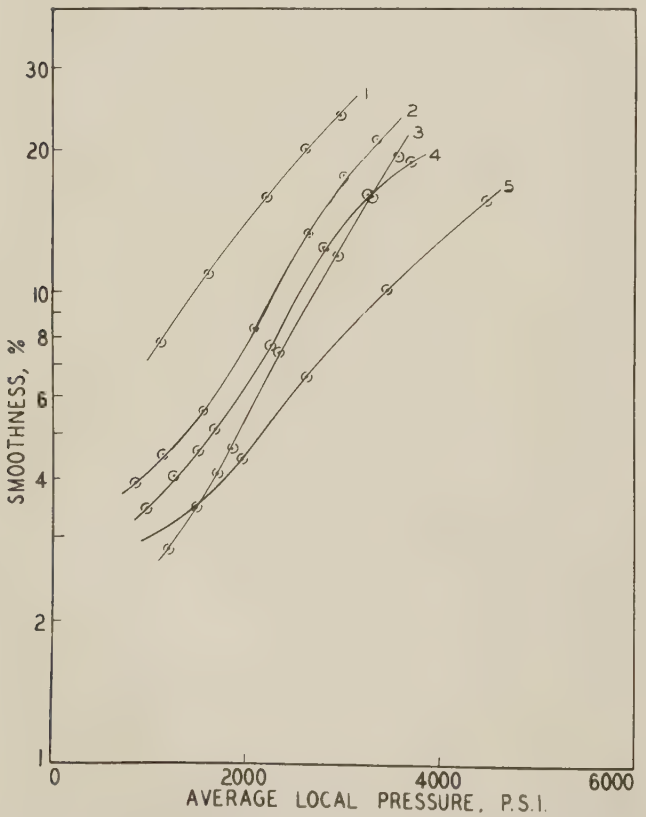


Fig. 11. Dependence of printing smoothness on average local pressure for a newsprint backed by different materials

1—Silicone rubber. 2—Offset press blanket. 3—News press blanket. 4—Glass. 5—Index card stock.

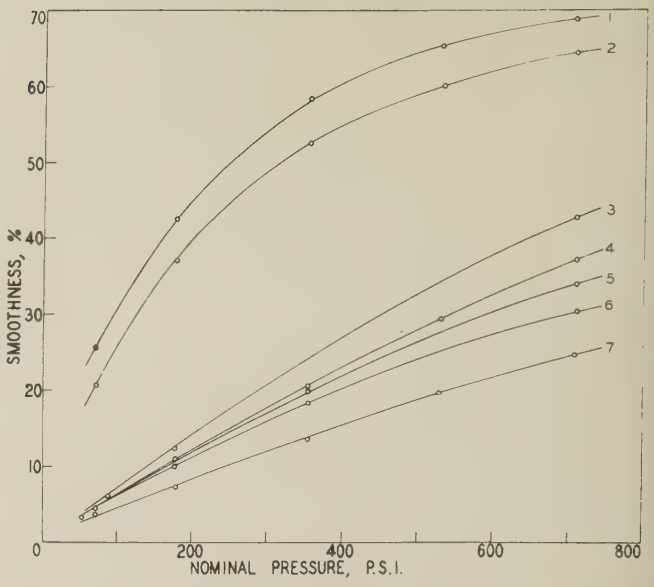


Fig. 12. Dependence of printing smoothness on nominal pressure for several coated papers backed by different materials

1—Cast-coated paper, offset blanket. 2—Cast-coated paper, glass. 3—Coated paper no. 3, offset blanket. 4—Coated paper no. 4, offset blanket. 5—Coated paper no. 3, tympan paper. 6—Coated paper no. 3, glass. 7—Coated paper no. 4, glass.

over the contact areas because at some areas of optical contact the specimen surfaces may bear little or no load while at others the load supported may be disproportionately high. However, in our efforts to determine the significance of printing smoothness data we have found it stimulating and helpful to make use of the average local pressure which is calculated by dividing the nominal pressure by the fraction of the specimen surface that is in optical contact with the prism face. For example, if the F value is 0.08 at a nominal pressure of 200 p.s.i., the average local pressure is 200/0.08 or 2500 p.s.i. Average local pressures were calculated from the data plotted in Fig. 8 and the Chapman printing smoothness values for the six papers are shown as a function of average local pressure in Fig. 9. To some extent this plot seems to spread the samples more than the plot of smoothness versus nominal pressure. The smoother sheets exhibit the steeper curves. There are occasions when it is interesting to plot the logarithm of printing smoothness as a function of the average local pressure or the logarithm of the average local pressure.

INFLUENCE OF BACKING MATERIAL ON CHAPMAN PRINTING SMOOTHNESS

Chapman (*1*) has indicated the influence of backing material on printing smoothness and on the distribution of contact areas in the Chapman instrument. A soft backing material leads to more uniform distribution of contact areas and to high printing smoothness values.

Additional data on the effect of backing material are presented in Fig. 10 which shows the printing smoothness—nominal pressure curves for a newsprint when backed by five different materials. The silicone rubber backing consisted of two 0.082-in. sheets of silicone rubber topped with a sheet of 0.001-in. thick cellulose acetate. The combination had a Shore hardness of 72 on the A scale. The newspaper press blanket was

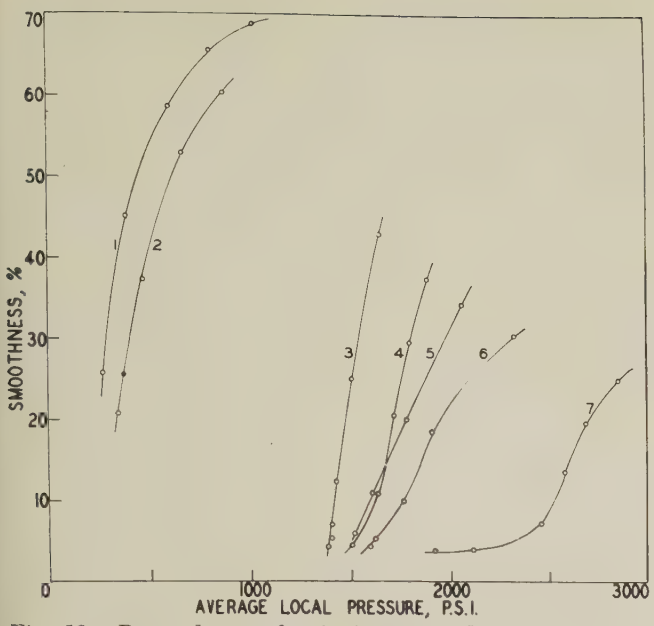


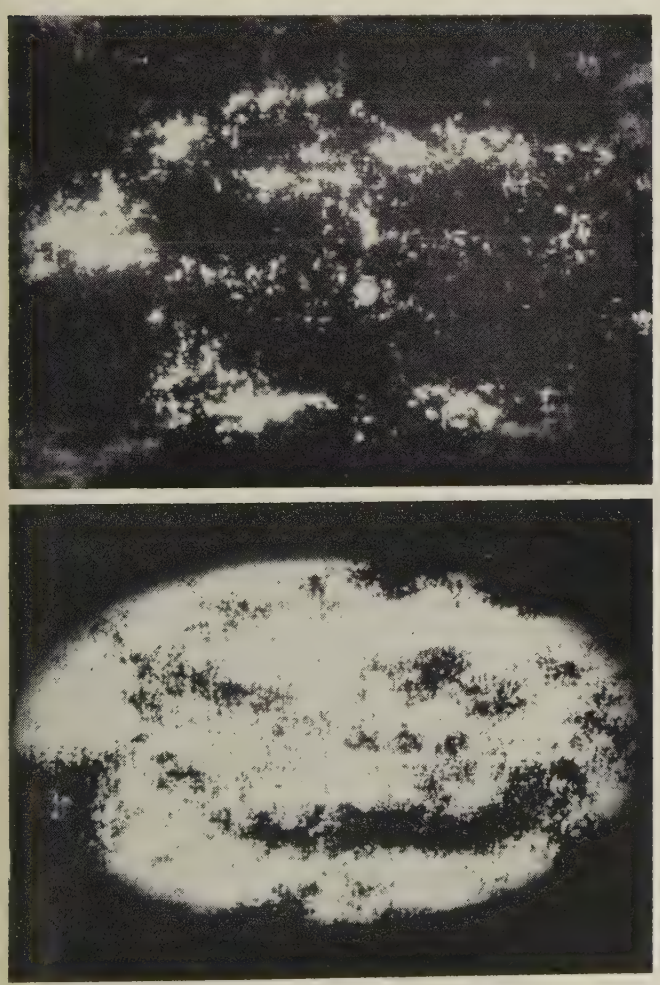
Fig. 13. Dependence of printing smoothness on average local pressure for several coated papers backed by different materials

1—Cast-coated paper, offset blanket. 2—Cast-coated paper, glass. 3—Coated paper no. 3, offset blanket. 4—Coated paper no. 4, offset blanket. 5—Coated paper no. 3, tympan paper. 6—Coated paper no. 3, glass. 7—Coated paper no. 4, glass.

three-ply and the index card backing consisted of four sheets of index card stock.

The newsprint was smoothest when backed by the silicone rubber. In second place among the backing materials was the offset press blanket. The crossing of the curves for plate glass and newspaper press blanket backings is considered to indicate that at lower pressures the nonuniformities in thickness of the blanket were not compensated for by its compression and the blanket was not as level a backing as the glass. At higher pressures the compression of the blanket more than compensated for the nonuniformities in thickness and the blanket distributed the applied load more uniformly than did the plate glass backing. Apparently the formation and uniformity of caliper of the index card stock were poor enough to more than compensate for the greater compression of the four cards compared to the plate glass. Figure 11 presents the same data in a plot of printing smoothness as a function of average local pressure.

The effect of backing material on the printing smoothness of three coated sheets is illustrated in Fig. 12. The change in smoothness with change from glass to offset press blanket backing was least, both percentagewise and in absolute value, for the cast-coated sheet and was greatest for coated sheet no. 4. In the case of coated sheet no. 3 the tympan paper backing was intermediate in effect between the glass and the offset press blanket. It is interesting to note, by comparison of Figs. 10 and 12, that the newsprint was less respon-



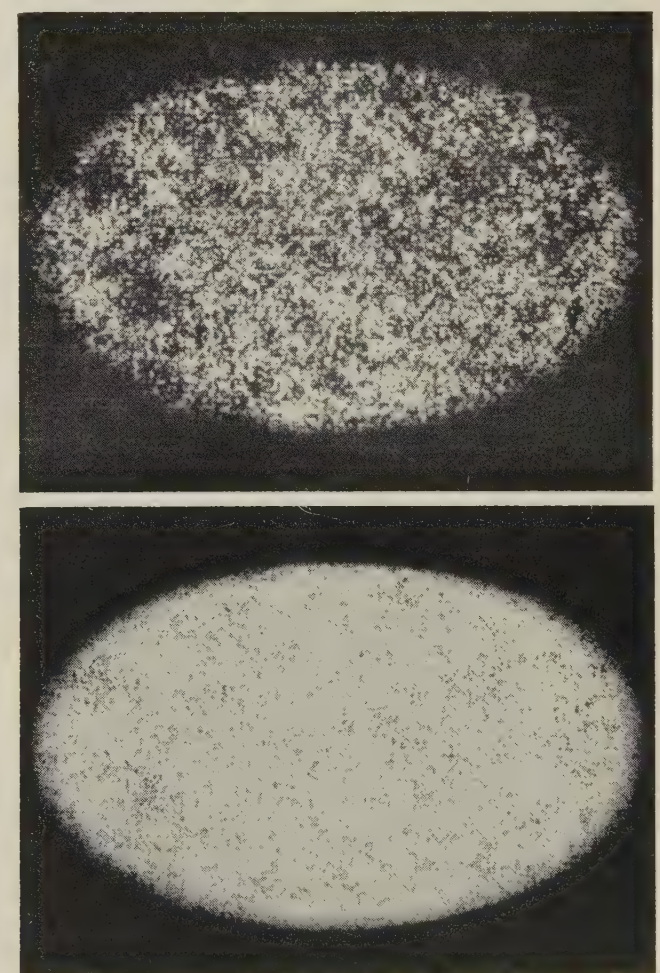


Fig. 14. Photographs illustrating different distributions of contact areas in the Chapman printing smoothness tester

Left, top—Coated paper no. 2 at 177 p.s.i. Left, bottom—Coated paper no. 2 at 708 p.s.i. Right, top—coated paper no. 5 at 177 p.s.i. Right, bottom—Coated paper no. 5 at 708 p.s.i.

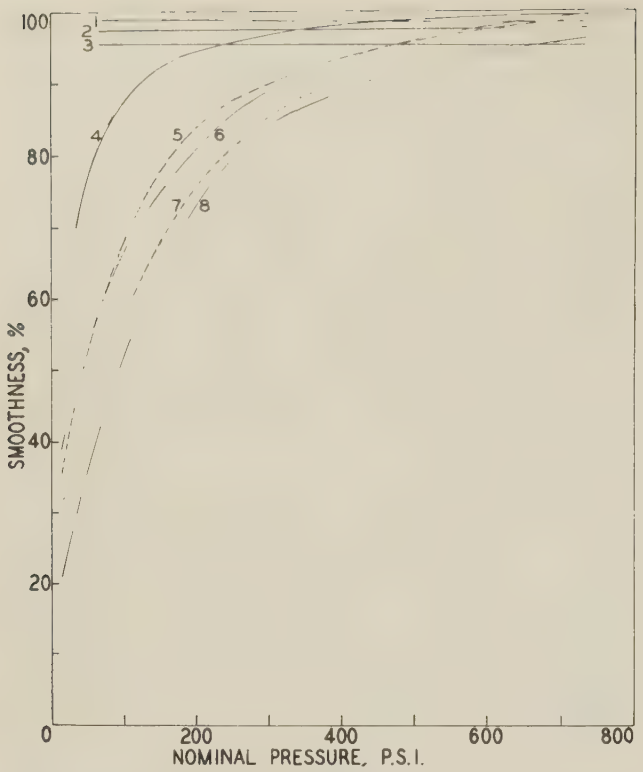


Fig. 15. Dependence of printing smoothness on nominal pressure for several rubber sheets and offset press blankets

1—Silicone rubber, 0.164 in. thick. 2—Silicone rubber, 0.082 in. thick. 3—Buna rubber. 4—Cellulose acetate film 0.001 in. thick, over silicone rubber, 0.164 in. thick. 5—Offset press blanket no. 1. 6—Offset press blanket no. 2. 7—Offset press blanket no. 3. 8—Offset press blanket no. 4.

sive to the change from glass to offset blanket backing than any of the coated sheets. It is also apparent from comparison of Figs. 8, 10, and 12 that typical newsprints have printing smoothness values in the same range as some coated sheets. The data of Fig. 12 are also presented in Fig. 13 as a plot of printing smoothness as a function of average local pressure.

It appears that the softer backing aids in distributing pressure over the large-scale irregularities in the sheet and thereby improves the smoothness of the surface. However, many surface irregularities resist the deformation necessary to bring them into contact with the prism, even with soft backing. The response of the sheet to change from hard to soft backing at the higher pressures may prove to be an indirect measure of conformability of small surface elements in the sheet.

VISUAL OBSERVATION OF SPECIMENS IN THE PRINTING SMOOTHNESS TESTER

The surface of specimens under pressure in the tester may be observed and photographed through the viewing prism. When the eye is raised so that angle of viewing is within the critical angle, the entire illuminated surface of the specimen is visible. When the eye is lowered so that the angle of viewing is greater than the critical angle, only the portions of the specimen surface that are in optical contact with the prism are seen. The patterns of the in-contact areas differ greatly among papers. In some cases the individual spots or areas of contact are small but relatively uniformly distributed over the surface at low pressures. As the pressure is increased, the number, and to some extent the area, of the individual spots of contact increase, still with uniform distribution over the specimen surface. At the highest pressure the spots of contact are densely distributed with no large noncontact areas between them. In other cases the contact areas may be very nonuniformly distributed and large, giving the specimen a blotchy appearance. These extremes of behavior are illustrated by the photographs in Fig. 14 which shows the appearance of two coated sheets at low and high pressures. The specimens were backed by the offset blanket. Even with this soft backing there were large areas of coated sheet no. 2 that were not forced into contact with the prism at the higher pressure, 708 p.s.i. The F-values at this pressure were 55.2% for coated sheet no. 2 and 29.0% for coated sheet no. 5. However, it is not uncommon to observe pronounced differences in the distributions of contact areas for specimens having nearly equal F-values. In the comparison of papers with regard to printing smoothness, it is desirable to observe the distribution of contact areas as well as the F-values.

It has been interesting to observe the appearance of printed sheets when under pressure in the instrument. The specimen is placed in the instrument with the printed surface against the prism. With the line of sight within the critical angle one can look for unsatisfactorily inked areas in the print and then, by lowering the eye, one can note whether the poorly inked area disappears, in which case the area is not in contact with the prism and may be termed a pit in the paper surface.

In the case of gravure prints there is a range of pressure in which many skips (failure of gravure cells to print) correspond to pits in the paper surface. The correlation depends to some extent upon the backing material. The correlation is good enough to indicate that smoothness of the paper surface under pressure is an important requisite for good gravure printing. At low and high pressures the correlation between skips in the print and pits in the surface is not good. At low pressures there are many pits which do not correspond to skips and at high pressures there are many skips which do not correspond to pits. The Chapman instrument may thus be helpful in determining indirectly the pressures employed in gravure printing. It is our current opinion that these pressures are commonly of the order of 300 p.s.i.

In the case of letterpress prints from thin ink films there is also some correlation of poorly inked areas with pits in the paper surface. This correlation is found in both solids and half-tones. The uninked areas are sometimes sharply defined by the perimeter of a pit in the paper surface. When thick ink films are used, this correlation between poorly inked areas and pits is poor or nonexistent. This is to be expected for, as Chapman (*1*) noted, there is no liquid film on the surface of the prism to correspond to the ink film on the printing form. The ink on the form reaches into pits in the paper surface which are not forced into contact with the prism of the smoothness tester.

In the visual examination of newsprints in the instrument we have used magnifications up to 20×. The small individual areas of contact which are observed at low pressures increase only slightly in size as the pressure is increased. It is the number of small

contact areas that increases with pressure and leads to the increase in total contact area. The individual areas are small portions of the surfaces of individual fibers and groundwood particles. In no newsprint yet examined have continuous areas of contact as large as a 65-line, 10% half-tone not been observed at any pressure up to 700 p.s.i.

SMOOTHNESS OF RUBBER SHEETS AND OFFSET PRESS BLANKETS

When rubber sheets are tested according to the procedure used for paper specimens, the smoothness values are found to increase rapidly with increasing pressure and it is not uncommon for them to exceed 100% at the higher pressures. For example, at 700 p.s.i. the *F*-value for a silicone rubber was 105.5% and at 350 p.s.i. the value for a sponge rubber was 113.4%. Smoothness values which exceed 100% (perfect contact with the prism) are meaningless. It seems likely that the reason for this discrepancy lies in a tacit assumption of Chapman's theory—viz., that the angular distribution of reflected light is similar for the glass standard and all specimens. This intensity distribution function is included in the instrument constants, *M* and *N*, determined by use of the glass standard.

The use of a ground opal glass surface for calibration prior to the testing of papers is appropriate because the glass and many surfaces are generally similar in their angular distributions of reflected light and, importantly, because the glass is impervious to the oil used to produce the 100% optical contact condition. In the case of a specimen which is impervious to oil, it seems logical to use the specimen itself as the calibrating surface. This procedure for determining the instrument constants was used for a number of rubber sheets and offset press blankets and the smoothness values subsequently obtained are presented in Fig. 15. Each specimen was backed by plate glass. *F*-values significantly greater than 100% were not observed. It is apparent that even these relatively soft and deformable surfaces differ significantly in smoothness at the lower pressures. This evidence of smoothness variation may be of interest in considering the performance of offset press blankets and rubber plates. In connection with rubber surfaces of these types it would be interesting to search for a relationship between the data obtainable with this smoothness test and with the conformability test of Bekk (*3*).

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The major part of the data presented in this paper resulted from a study of testing methods for printability of newsprint which is being carried on by The Institute of Paper Chemistry on behalf of the American Newspaper Publishers Association. Progress reports on this study were presented in the American Newspaper Publishers Association Technical Reports No. 1 (Oct. 8, 1951) and No. 16 (Nov. 6, 1953).

The Chapman Printing Smoothness Tester

III. Design and Use of a Direct Reading Tester

D. NOEL OBENSHAIN

This paper covers the design, construction, and use of direct reading Chapman printing smoothness testers built by the West Virginia Pulp & Paper Co. at its Luke, Md., research laboratory. Five of the instruments have been built to date for use in the company's laboratories. Considerable work has been done with the original tester. The instrument is a rugged, compact, self-contained unit which automatically indicates on an easily read dial the Chapman *F* value of the sample of paper clamped therein. All controls are conveniently arranged for ease of operation. Special design features make the instrument substantially immune to damage by accidental misuse. Data presented on operation of the tester show very good correlation with printability. Included are some photographs of typical paper surfaces as viewed through the Chapman tester and the same papers as viewed through a low-powered microscope with the surfaces illuminated at a very flat angle. The calculations for a typical dial calibration, and a complete list of parts for the instrument, are given in the appendix.

The West Virginia Pulp & Paper Co. has always been interested in better ways of evaluating the properties of papers. Ways and means of determining the printing characteristics of paper have been of particular interest. Smoothness is considered one of the important properties directly affecting printing, so naturally, interest was shown in the new smoothness tester announced by Mr. Chapman in 1947.

When The Institute of Paper Chemistry at Appleton, Wis., constructed a model of the Chapman tester and had made preliminary evaluation of it as described in the American Newspaper Publishers Association's Technical Report No. 1 of Oct. 8, 1951, samples of various company papers were submitted to the Institute for evaluation with their new tester.

The resulting data proved quite interesting and merited consideration of building a Chapman tester for use in West Virginia's own testing laboratories. The job of designing and building the instrument was assigned to the research laboratory at the Luke mill of the company. Permission was obtained from Mr. Chapman to use the principles and basic design which he had developed.

D. Noel Obenshain, Research Engineer, West Virginia Pulp & Paper Co., Luke, Md.

Experience with numerous instruments used in control laboratories indicated that for satisfactory operation the instrument should have the following listed characteristics: (1) rugged, (2) simple to use, (3) easy

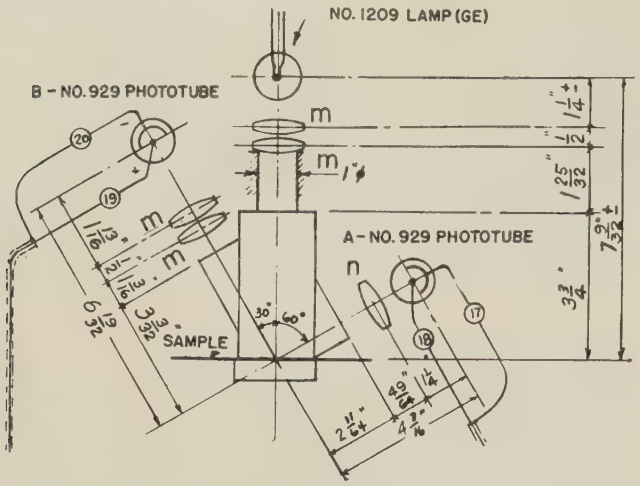

Fig. 1. Optical system

Lens m, Achromat, 34 mm. diam × 65 mm. F. L.
Lens n, Double convex, 29 mm. diam. × 26 mm. F. L.

to read, (4) easily standardized, (5) stable over long periods, (6) self-contained, (7) easily serviced, and (8) pleasing in appearance.

All these points were kept in mind in the design which will be described herewith.

THE OPTICAL SYSTEM

The optical system for the instrument is essentially that of Mr. Chapman's design. The prism assembly

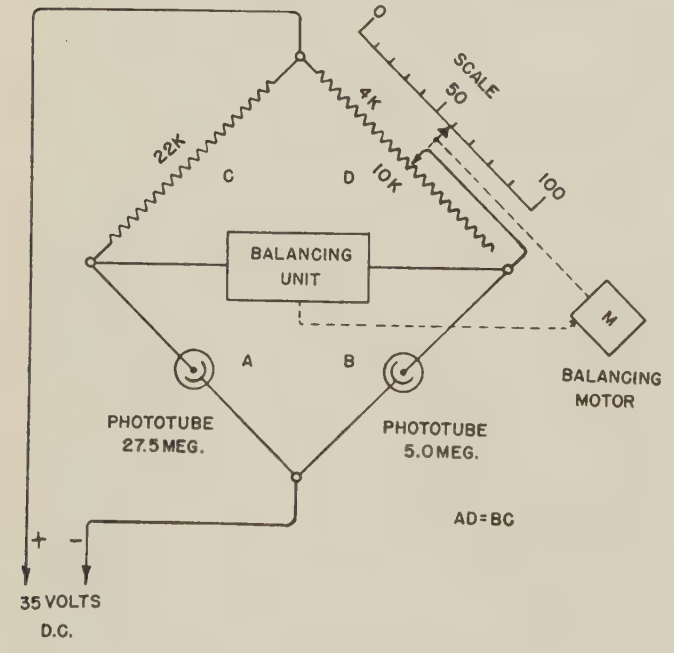

Fig. 2. Basic bridge circuit

has exactly the same specifications. The lens systems are somewhat modified to accommodate phototubes and permit use of a symmetrical housing design. Figure 1 gives specifications and locations of the various optical elements. Since the lamps which Mr. Chapman used are no longer available, the design was switched to a standard G.E. no. 1763, 6 to 8-v. prefocused instrument-type lamp. The lamp mounting is adjustable in all directions to permit focusing a 1-in. diameter light spot at the center of the bottom face of the prism. After initial adjustment, the lamp may be replaced without further adjustments. A pigtail connector is soldered to the end contact of the lamp to insure a dependable connection at this point.

THE MEASURING SYSTEM

In view of adverse experiences with barrier layer photocells and sensitive galvanometers in other laboratory instruments, it was decided to go to vacuum photo-

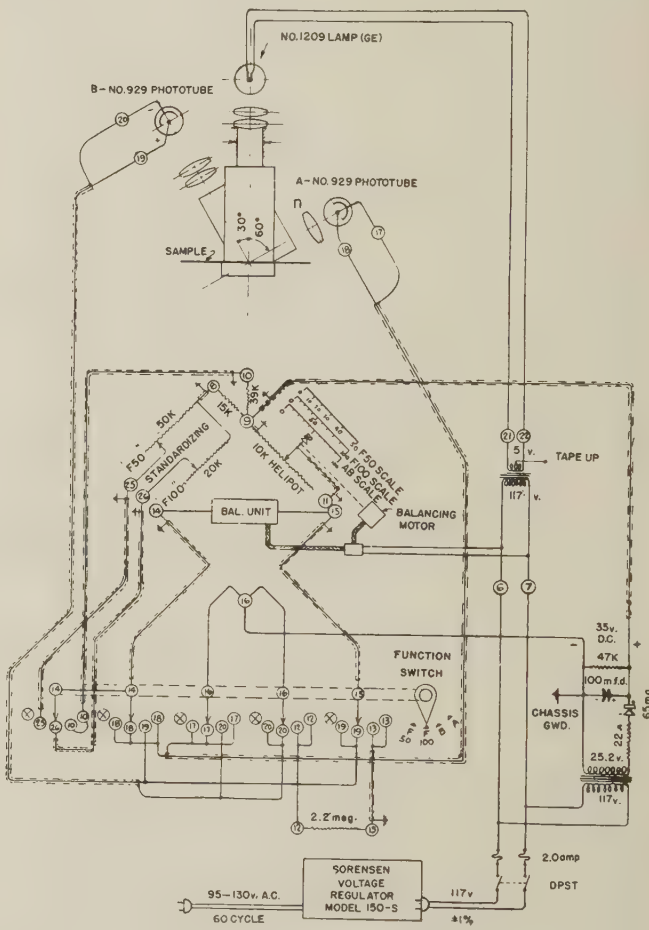

Fig. 3. Circuit diagram

tubes and a self-balancing resistance bridge circuit. The basic bridge circuit is shown in Fig. 2. Phototube A receives light from the area of the sample in optical contact with the bottom surface of the prism while phototube B receives light from the entire area, as explained by Mr. Chapman in his theory of the instrument.

In the simple Wheatstone bridge circuit used, the bridge is balanced, that is, there is no current flowing through the balancing unit when resistances,

$$AD = CB \qquad (1)$$

or,

$$D = CB/A \qquad (2)$$

or,

$$D = \frac{C}{A/B} \qquad (3)$$

With C as a constant, it will be seen that D will have to vary inversely as the ratio A/B to keep the bridge circuit balanced. Thus, any position of the slider on slidewire D is linearly proportional to the light received by phototubes A/B. The white standardizing glass with oil contact gives the maximum A/B value. If by means of calibrating resistor C this is made to read 100% on the D resistor, then the linear scale attached to D would read directly the light value ratio A/B.

For any A/B ratio there is a definite F value as shown

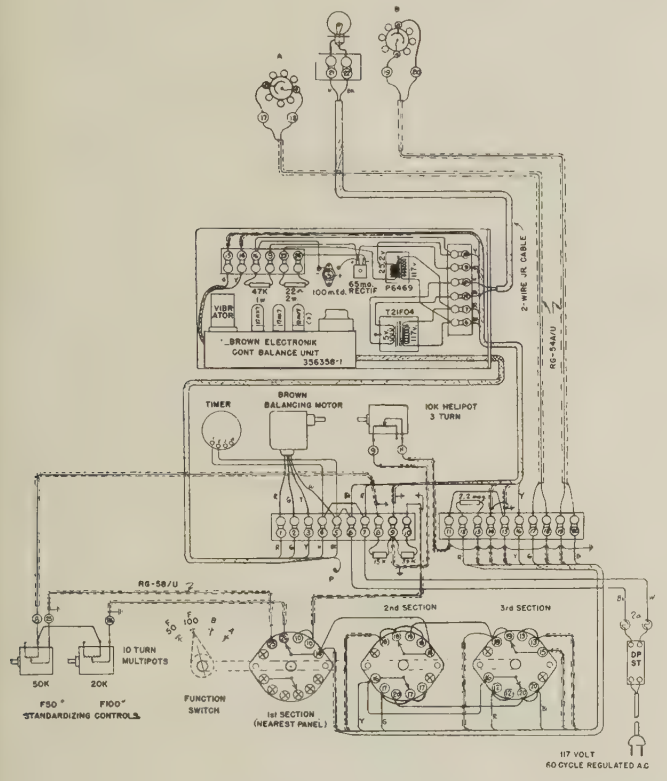

Fig. 4. Wiring diagram as viewed from back of instrument. Note: All coaxial cables except leads to photubes to be type RG 58/u

by the following rearrangement of the basic Chapman formula.

% Contact	$F = M/(N + B/A)$ basic formula	(4)
Ratio	$A/B = F/(M - FN)$	(5)

Once the constants M and N have been determined for a given instrument, the F scale calibration in terms of A/B can be calculated for as many points as desired, usually at 5% F value intervals. This permits easy location of the F points using the uniformly divided AB scale as a reference. The F scale can be readily expanded to give less total range with wider divisions at the lower values where most papers will fall. Papers having F values over 50 are quite rare. Scale expansion is accomplished by increasing calibrating resistor C. Calculations for a typical scale calibration are give in the appendix.

Figure 3 shows the complete circuit diagram for the instrument. The function switch shown permits reading the relative amounts of light received by the individual phototubes A and B as well as providing two

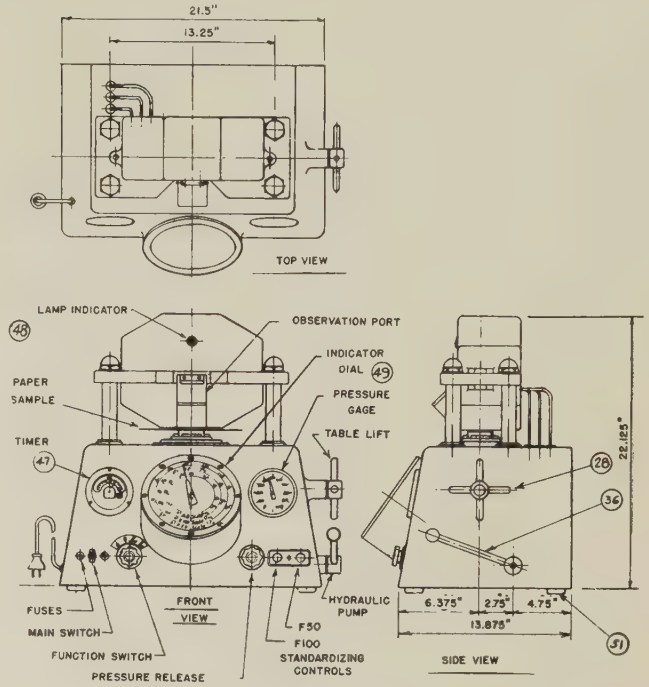

Fig. 5

ranges of F values, 0–100 and 0–50. The individual A and B values are needed for determining the instrument

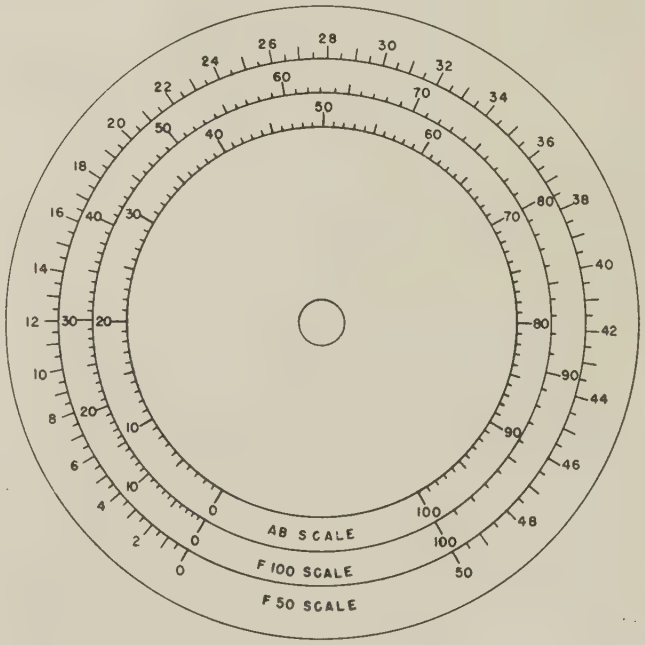

Fig. 6. Typical scale calibration

constants M and N. It will be noted that three calibrating resistors are employed, a fixed 39 K resistor for reading the A and B values, an adjustable 20 K resistor for standardizing the F 100 scale, and an adjustable

50 K resistor for standardizing the F 50 scale. When reading the *A* and *B* values, the 2.2-megohm resistor shown below the function switch is inserted in the circuit in place of phototube B in Fig. 2. Phototubes A and B are then separately inserted in phototube A's normal position for reading their respective values.

The phototubes are vacuum type RCA no. 929 having standard octal bases. These were selected because of their linearity, stability, and color characteristics. They are relatively insensitive at the red end of the spectrum and thus will not be affected by heat of the instrument parts. Phototubes for a given instrument should be approximately matched in their output characteristics. Phototubes bought from dealers' stocks will vary quite widely in output.

The balancing unit and balancing motor are standard

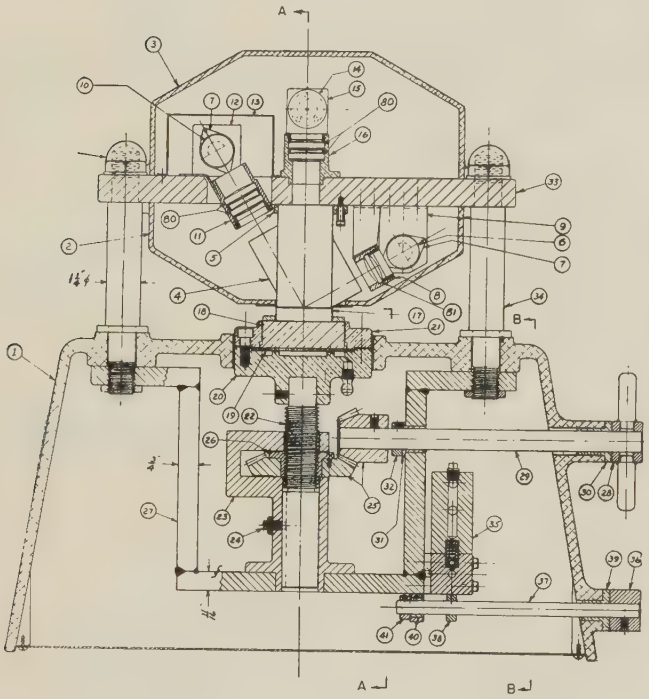

Fig. 7. Sectional view

Brown Electronik components. Similar equipment of other manufacture ought to function in like manner.

The d.c. power supply for the bridge circuit is provided by a small 117/25-v. transformer with a selenium rectifier, 100-mfd. capacitor, and a 47K bleeder resistor. The d.c. output is approximately 35 v. While the phototubes are suitable for a maximum of 250 v., long time stability is much better with the lower voltage.

Alternating current lamp supply is from a 117/5-v. transformer. A Sorensen model 150-S voltage regulator, separate from the instrument, is used to maintain voltage to the instrument constant plus or minus 0.1%. When reading *F* values, a voltage regulator is not absolutely essential for normal line fluctuations since the two phototubes tend to balance out variations in lamp intensity. When reading individual *A* and *B* values, the voltage regulator is quite necessary since only one phototube is used at a time.

Since resistances of the phototubes are very high and currents in the measuring circuit are very low, it has been found necessary to use coaxial cable for all wiring of the ungrounded circuits in the measuring system to avoid stray current pickup and to minimize capacitance.

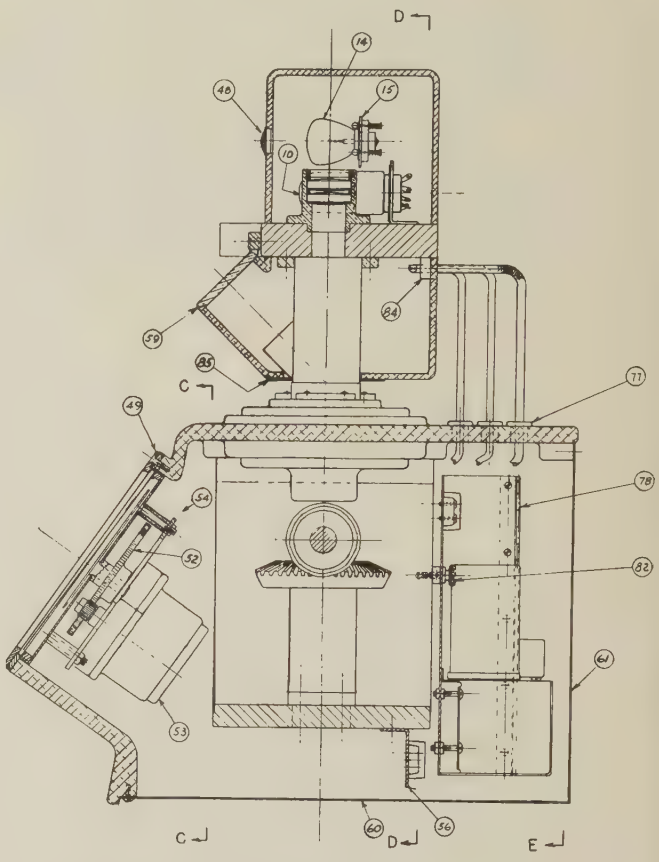

Fig. 8. Section A-A

effects. RG-58/U cable functions quite well in this service. The shield conductor is grounded in all cases.

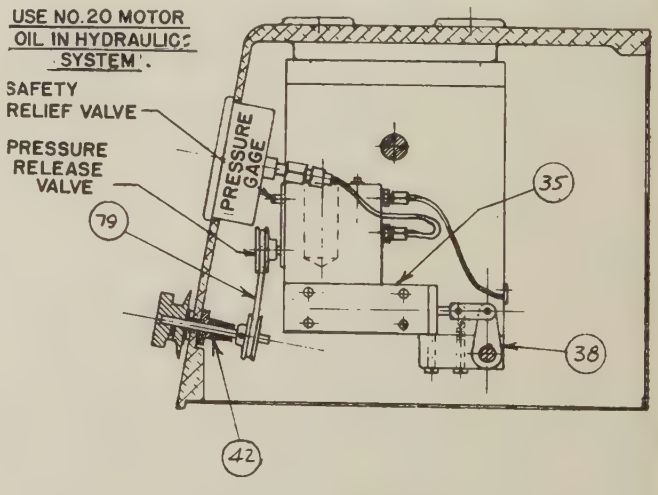

Fig. 9. Section B-B

A complete wiring diagram of the instrument is shown in Fig. 4. It will be noted that wiring is brought out to appropriate terminal strips for ease in checking and servicing.

MECHANICAL DESIGN

While the basic instrument varies but little from the original Chapman design, the various components have

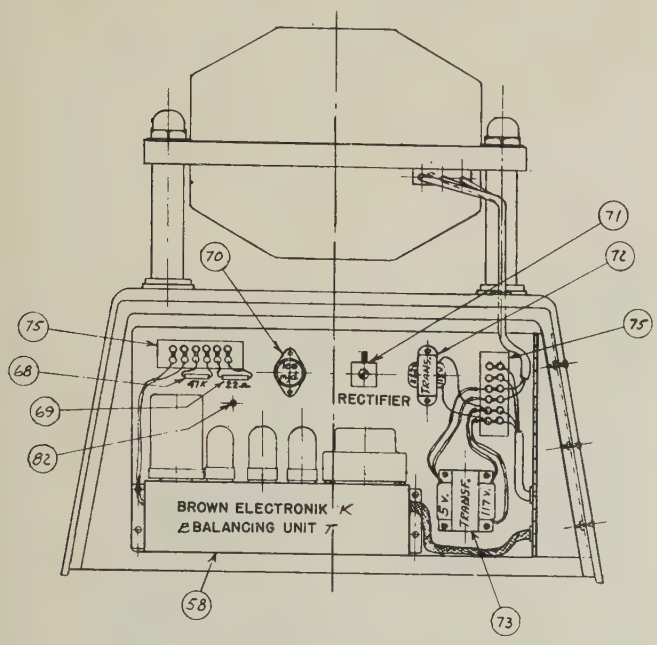

Fig. 10. Section E-E

been assembled in a single housing, and the controls have been arranged for ease of operation.

Figure 5 gives front, side, and top views of the instrument. The various dials and controls are identified

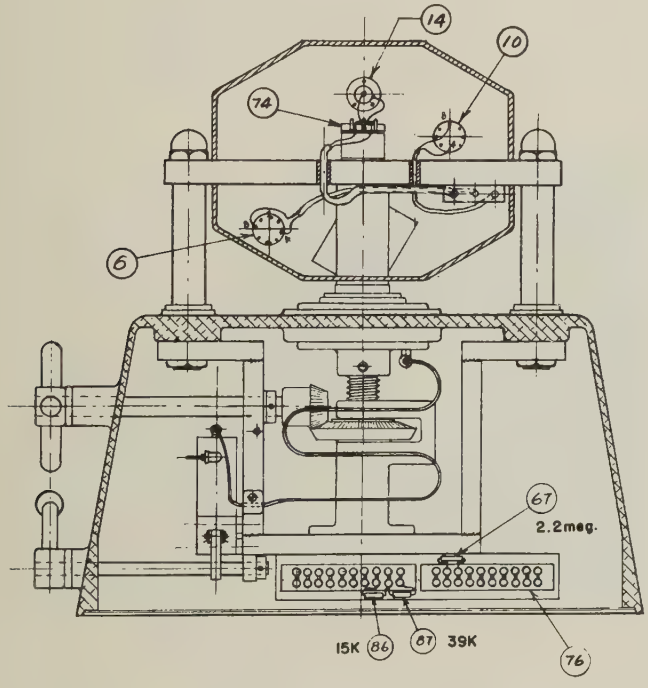

Fig. 11. Section D-D

in these views. The pressure gage is calibrated to read directly in pounds per square inch of pressure on the paper. The interval timer is used as an indicator only. It eliminates the need of a stopwatch to determine the proper time after applying pressure before taking the dial reading. It is adjustable up to 120 sec. The two standardizing control knobs have a transparent cover over them to avoid accidental turning.

The main indicating dial has three scales, AB which is uniformly divided 0 to 100, an F 100 scale, and an F 50 scale. The F 100 scale is colored red and the F 50 scale, green. The rest of the dial is white. The indicator pointer is black. A typical scale calibration is shown in Fig. 6. Calculations for the dial are given in the appendix.

Sectional views, Figs. 7 and 8, show the general mechanical features of the instrument. The part numbers in circles refer to the complete parts list contained in the appendix. Figure 9 gives the arrangement of the hydraulic pump and its piping. Figure 10 is a back view of the instrument with the back cover removed. The electronic equipment mounts on a hinged panel 78 which may be swung outward to give access to the hydraulic pump and the table lifting mechanism.

Figure 11 is a back sectional view showing the table

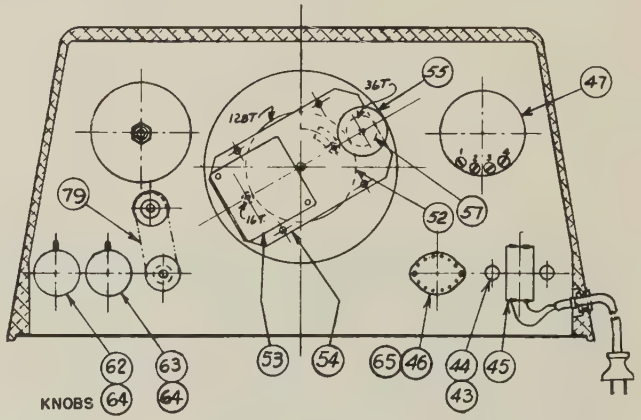

Fig. 12. Section C-C

lifting mechanism and terminal strips. Figure 12 shows a back view of the front control panel. The complete dial assembly including motor and slidewire can be removed from the front of the case as a complete unit for inspection and adjustment. Lead cables to the dial are long enough to permit this without disconnecting.

Several features are incorporated in the instrument to prevent damage by accidental or incidental misuse. The hydraulic pump is equipped with a pressure relief valve so that excessive pressure cannot be applied to the loading diaphragm 19 and thence to the glass prism. Loading plate 18 which transmits the diaphragm pressure to the glass platen 17 has a rim at its bottom so that its travel is limited to $^1/_8$ in. This would prevent possible damage to the diaphragm should someone operate the hydraulic pump when the table is not elevated to operating position. The pressure release knob is coupled to the control valve by means of a heavy rubber band so that the valve cannot be jammed and damaged.

The entire instrument can be left turned on indefinitely without damage except to lamp and balancing

unit tube life. The phototubes should last for several years of continuous use. The lamp should last for several months of continuous use. It can be easily

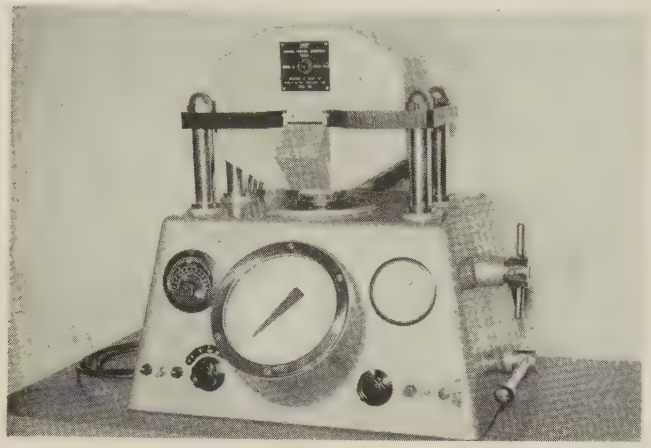

Fig. 13. Front view

replaced by removing the top cover 3 which is held in place by two $^1/_4$-in. cap screws.

The only part of the instrument that can be easily damaged is the bottom face of the glass prism which can be scratched by careless cleaning. If accidentally scratched it can be repolished by the original manufacturer or other qualified optical service house.

Figures 13, 14, 15, and 16 are photographs of the instrument. In Fig. 16 the top cover is removed showing the lamp mounting.

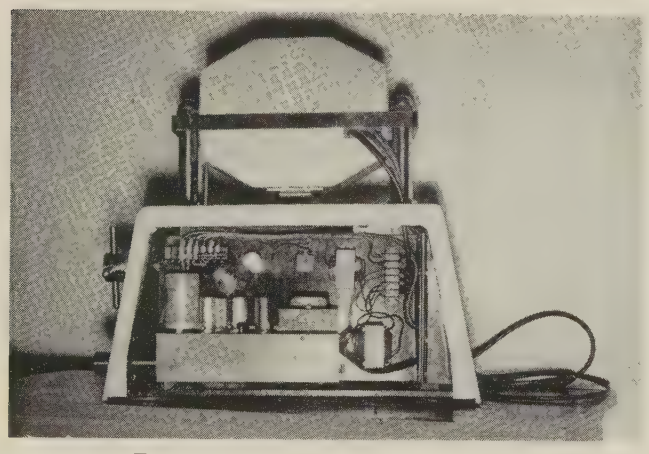

Fig. 14. Back view, cover removed

OPERATING THE TESTER

Operation of the tester is relatively simple and can be performed by semiskilled control laboratory personnel. The prism face is first checked for cleanliness by looking in the observation port. If necessary, it is cleaned by wiping with a lens or eyeglass polishing tissue. The function switch is turned to the proper range. The sample is then inserted, the platen table elevated by means of the handwheel to give contact with the prism, the release valve is closed, and pressure is applied with the hydraulic pump. The timer button is pressed when the desired pressure is reached and when its pointer flies back the dial reading is taken and recorded. Several readings may be taken on a sample and averaged if prescribed. The observation port *must* be closed when taking readings, otherwise light from the room may cause false readings.

CALIBRATION

The instrument will ordinarily hold its calibration for several days. For precise work it should be checked once every 24 hr. A very simple check can be made by placing a sample of paper in the tester, taking A, B, and F readings in quick succession, then calculating the F value from the A and B values using the basic Chapman formula given below.

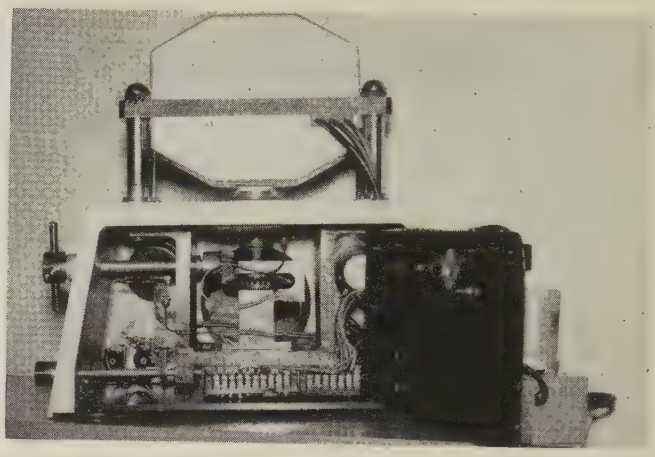

Fig. 15. Back view, showing elevating mechanism

$$F = M/(N + B/A) \qquad (6)$$

It will, of course, be necessary to have the instrument constants M and N to make this check. If the indicated F value and the calculated F value do not check, then proceed as follows.

Fig. 16. Top view, lamp cover removed

Be sure the prism face is clean. If necessary clean with carbon tetrachloride, using a small piece of new cheesecloth. Then polish with lens tissue. Clean the white glass standard with carbon tetrachloride. Place a small pool of clear mineral oil—about 2 drops— at the center of the standard and place standard on the lowered platen. Elevate the platen until the oil touches the

prism and apply enough pressure with the handwheel—do not use hydraulic pump—to cause the oil film to spread over the bottom of the prism as noted through the observation port. It is not necessary that the oil extend all the way to the corners as long as it goes to all sides of the prism. If air bubbles have been trapped in the oil film and cannot be removed by handwheel pressure, it may be necessary to remove the standard, clean both it and the prism with carbon tetrachloride, repolish the prism, and repeat the procedure.

Now *close* the observation port and with function switch in the F 100 position, check reading of the pointer. If it does not read exactly 100, remove cover from the standardizing controls and adjust the F 100 control until it does. Space for pointer overtravel of about $^1/_4$ in. past the 100 point is provided. Now remove the standard from the instrument, clean both it and the prism face with new cheesecloth and carbon tetrachloride, and repolish the prism with lens tissue.

If it has been found necessary to adjust the F 100 standardizing control, it will also be necessary to adjust the F 50 standardizing control. To do this, insert a piece of paper in the instrument having a smoothness of around 30 to 40, apply hydraulic pressure until the pointer comes to rest at some point on the F 100 scale with the function switch in the F 100 position. Be sure the pointer has stopped drifting. Then move the function switch to the F 50 position and adjust the F 50 standardizing control until the pointer reads the same on the F 50 scale as it did on the F 100 scale. Turn the function switch back and forth several times to be sure the two scales match.

A slight reversible drift of the instrument can be caused by changes in ambient temperature. As with most other paper testing instruments, it is preferable to use the Chapman tester in a constant temperature and humidity room. It is also desirable to allow the instrument to warm up for about 30 min. before using or standardizing. Where the instrument is being used for 24-hr. per day testing, it should be kept turned on continuously, even though samples may be tested only once every hour or so.

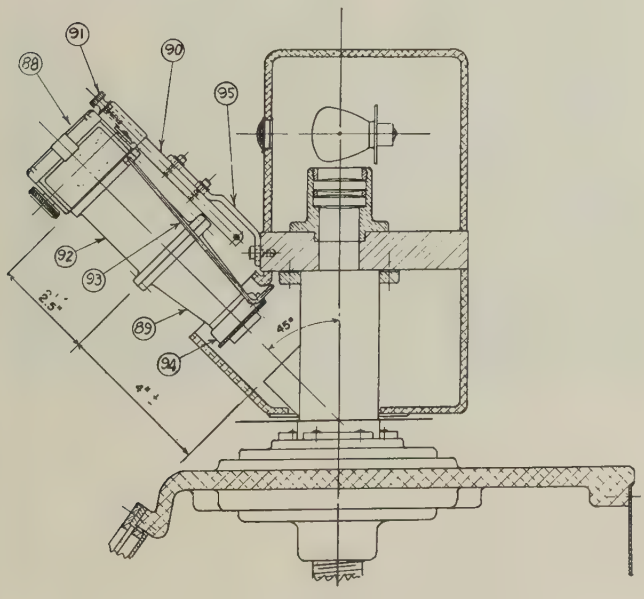

Fig. 17. Photographic attachment

PHOTOGRAPHING ATTACHMENT

A simple attachment for taking photographs through the observation port is shown sectionally in Fig. 17.

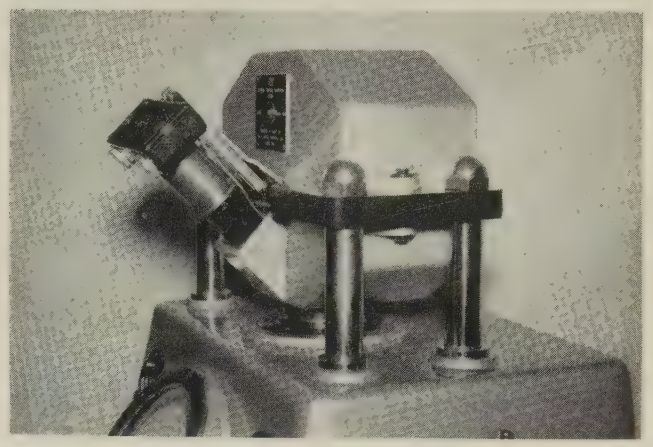

Fig. 18. Photographic attachment

Figure 18 is a photograph of the attachment. The camera body is from a "Histoslide" photomicrographic camera kit made by the Histoslide Co., Inc., Chicago, Ill., and sold through most laboratory supply houses. It uses standard 35-mm. film. A special extension tube, mounting bracket, and shutter release are required. The simple shutter assembly supplied with the camera is replaced by a Wollensak 2-in. F/3.5 anastigmat lens with no. 0 Alphax shutter, nonsynchronized.

Magnification with the camera attached as shown is approximately 2:1. Projection enlargement to 20:1 gives good prints for visual study. Film used has been Kodak Plus X with around 3-sec. exposures at F 32 diaphragm opening. The exact exposure for a given instrument would have to be determined experimentally. Pressure at 250 p.s.i. seems to give better pictures for visual evaluation than at the normal reading pressure of 700 lb.

DATA ON THE USE OF THE INSTRUMENT

While five instruments have been built, only one has been in service for any length of time. Some of the data from the use of this instrument are given herewith. The data are not at all complete and conclusions as to the value of the Chapman tester will have to be considered in that light.

The following correlations were determined by testing 160 samples of machine-coated publication papers. Three Chapman values and three gloss values were read on each sample, which sample was also printed on a Vandercook proof press for printability evaluation.

Basis weight coated sheet lb./ream 25 × 38—500	*Correlation values*			
	Printability vs. Chapman smoothness	*Printability vs. B. & L. gloss*	*Printability vs. $\sqrt{(gloss)(CPS)}$*	*Gloss vs. Chapman smoothness*
50	0.9035 (E)	0.9099 (E)	0.9262 (E)	0.9050 (E)
55	0.6899 (G)	0.9235 (E)	0.9353 (E)	0.7469 (G)
60	0.7267 (G)	0.8270 (E)	0.9192 (E)	0.4899 (F)
70	0.6355 (G)	0.9099 (E)	0.9016 (E)	0.7516 (E)

It is interesting to note that the value obtained by taking the square root of Chapman smoothness times gloss gives better correlation with printability than either value alone. The scale used in judging the above

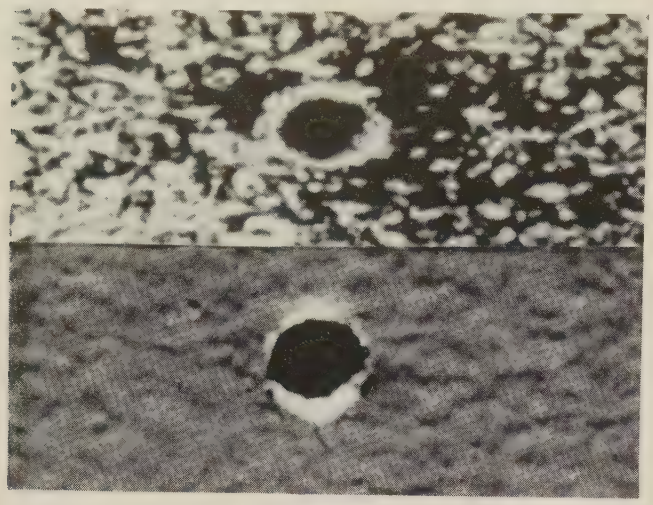

Fig. 19. Intaglio offset coated. Top, Chapman tester; bottom, flat lighting. Gloss-62; Chapman F-34.7

correlation values is based on the following:

0.7500 to 1.0000	Excellent (E)
0.5000 to 0.7500	Good (G)
0.2500 to 0.5000	Fair (F)
0.0000 to 0.2500	Doubtful (D)

The excellent correlation of gloss and printability

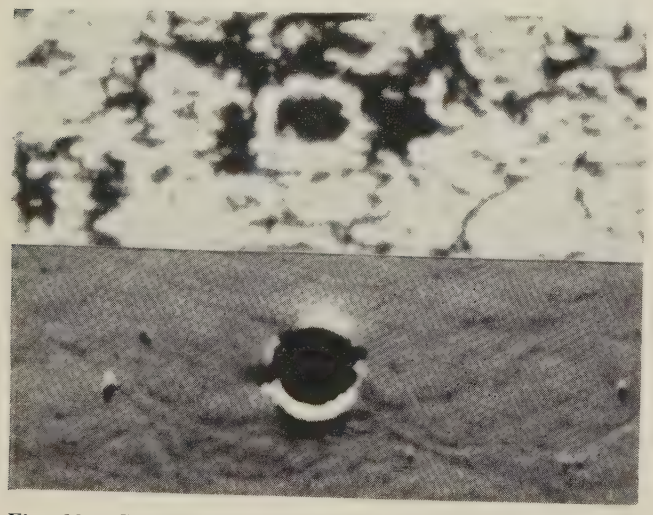

Fig. 20. Cast coated. Top, Chapman tester; bottom, flat lighting. Gloss-57; Chapman F-43.0

would not be expected with papers of somewhat different types. While correlation of rotogravure printability with Chapman studies has not yet been completed, indications are that it will be very good.

CHAPMAN VERSUS MICROSCOPE PHOTOGRAPHS

Surface photographs of over 60 different papers have been taken with the Chapman tester and also with a low-powered microscope viewing the paper normal to the surface with very flat lighting, approximately 85° from normal. Figures 19, 20, 21, and 22 show four pairs so obtained. Magnifications are 20 to 1. Two hundred and fifty pounds per square inch pressure was used on the Chapman tester for the photographs and 700 p.s.i. for the *F* values. The Chapman views are, of course, foreshortened in one direction due to the 45° viewing angle. A small hole was punched in each sample for use as a reference point in making comparisons.

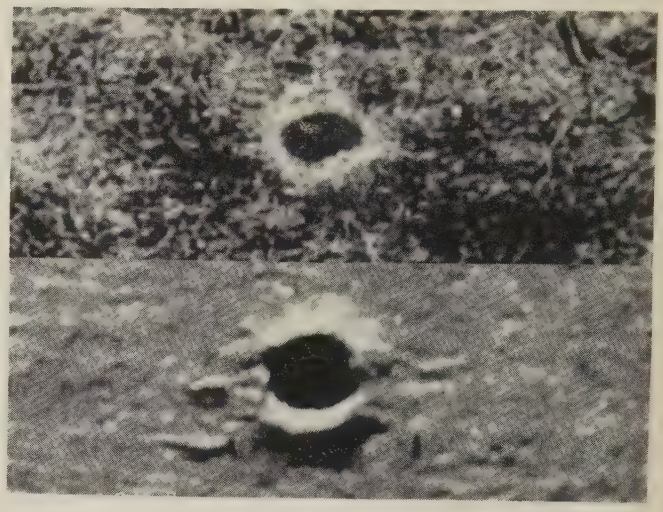

Fig. 21. Uncoated, supercalendered. Top, Chapman tester; bottom, flat lighting. Gloss-18; Chapman F-18.3

Figure 19 is a high-grade machine-coated paper made on an intaglio offset type coater. Figure 20 is a so-called cast-coated paper. Figure 21 is a supercalendered uncoated paper. The fibers will be noted in the Chapman view. It has both low Chapman and gloss values. Figure 22 shows a coated paper having a low Chapman value and a high gloss. It was selected to show that a high gloss does not necessarily mean that the paper will

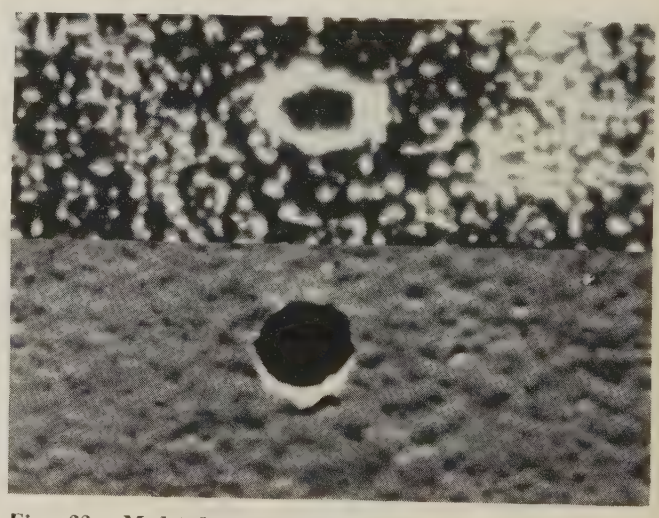

Fig. 22. Multiple-roll coated. Top, Chapman tester; bottom, flat lighting. Gloss-56; Chapman F-20.5

have a high Chapman smoothness value. Other samples not shown have high Chapman values and low gloss. Unfortunately, printability tests were not available on these samples illustrated.

APPENDIX

Calibrating the Instrument Dial

The Chapman calculations make use of the following terms and formulas:

A = Phototube A reading, paper sample (7)

A' = Phototube A reading, white glass at zero contact (8)

A'' = Phototube A reading, white glass with oil contact (9)

B = Phototube B reading, paper sample (10)

B' = Phototube B reading, white glass at zero contact (11)

B'' = Phototube B reading, white glass with oil contact (12)

$$\text{Constant } M = B'/A'' \quad (13)$$

$$\text{Constant } N = (B' - B'')/A'' \quad (14)$$

$$\%\ \text{Contact } F = M/(N + B/A) \quad (15)$$

$$\text{Ratio } A/B = F/(M - FN) \quad (16)$$

Since the A/B values can be plotted directly on the 0–100 uniformly divided dial scale, to plot the F scales, it only becomes necessary to determine the A/B values for a suitable number of F scale intervals. When the calculations are made it will be found that 0 to 100 of the F scale will cover considerably less span than the full dial capacity. It then becomes desirable to expand

For F 50 Scale

F, %	FN (F × 1.210)	M − FN (2.922 − FN)	A/B, % F/(M − FN)	S (See equation 19) (A/B × 463.4)
2	0.024	2.898	0.690	3.197
4	0.048	2.874	1.392	6.451
6	0.073	2.849	2.106	9.759
8	0.097	2.825	2.832	13.123
10	0.121	2.801	3.570	16.543
12	0.145	2.777	4.321	20.024
14	0.169	2.753	5.085	23.564
16	0.194	2.728	5.865	27.178
18	0.218	2.704	6.657	30.849
20	0.242	2.680	7.463	34.584
22	0.266	2.656	8.283	38.383
24	0.290	2.632	9.119	42.257
26	0.315	2.607	9.973	46.215
28	0.339	2.583	10.840	50.233
30	0.363	2.559	11.723	54.324
32	0.387	2.535	12.623	58.495
34	0.411	2.511	13.540	62.744
36	0.436	2.486	14.481	67.105
38	0.460	2.462	15.435	71.526
40	0.484	2.438	16.407	76.030
42	0.508	2.414	17.399	80.627
44	0.532	2.390	18.410	85.312
46	0.557	2.365	19.450	90.131
48	0.581	2.341	20.504	95.016
50	0.605	2.317	21.579	100.00

the A/B values so that F 100 is full scale, coinciding with 100 on the AB scale. The F 50 scale is likewise expanded so that F 50 coincides with 100 on the AB scale. The following formulas may be used:

$$S = \text{expanded } A/B \text{ value} \quad (17)$$

$$F_{max.} = \text{maximum } F \text{ value at full scale} \quad (18)$$

$$S = A/B\left[\frac{100}{(A/B)_{F_{max.}}}\right] \quad (19)$$

or

$$S = [F/(M - FN)]\left[\frac{100}{F_{max.}/(M - F_{max.}N)}\right] \quad (20)$$

For reasonable accuracy, S may be determined for every 5 points of F value. The divisions in between can be plotted with proportional dividers or similar devices. Or, S may be calculated for each point plotted when greater accuracy is required.

While equations (19) or (20) may be used to calculate each selected point separately, the tabular solution given below greatly simplifies the procedure. The data are typical for one of the instruments constructed.

For F 100 Scale

F, %	FN (F × 1.210)	M − FN (2.922 − FN)	A/B, % F/(M − FN)	(See Equation 19) (A/B × 171.2)
5	0.061	2.861	1.747	2.99
10	0.121	2.801	3.570	6.11
15	0.182	2.740	5.474	9.37
20	0.242	2.680	7.463	12.78
25	0.303	2.619	9.546	16.35
30	0.363	2.559	11.723	20.07
35	0.424	2.498	14.011	23.99
40	0.484	2.438	16.407	28.09
45	0.545	2.377	18.931	32.41
50	0.605	2.317	21.579	36.94
55	0.666	2.256	24.379	41.74
60	0.726	2.196	27.322	46.78
65	0.787	2.135	30.445	52.12
70	0.847	2.075	33.735	57.75
75	0.908	2.014	37.239	63.75
80	0.968	1.954	40.942	70.09
85	1.029	1.893	44.902	76.87
90	1.089	1.833	49.100	84.06
95	1.150	1.772	53.612	91.78
100	1.210	1.712	58.411	100.00

The A and B values obtained with the white glass standard were as follows:

$A' = 0.1$ (21)

$B' = 97.6$ (22)

$A'' = 33.4$ (23)

$B'' = 57.2$ (24)

$M = 2.922$ (25)

$N = 1.210$ (26)

The author wishes to thank the management of the West Virginia Pulp & Paper Co. for permission to use the subject matter contained herein, and to acknowledge the assistance and data provided by Kenneth H. Hunt and James D. Allen, the photographs by Harry F. Kohne, the drafting and design work by D. L. Green, and the excellent workmanship of A. M. Sively, laboratory shop supervisor, and his shop crew in building and working out details of the instrument.

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Parts List

Mark	*No. required*	*Description*	*Manufacturer*	*Mfg. part no.*
1	1	Case, cast aluminum	Piedmont Foundry	
2	1	Prism cover, cast aluminum	Piedmont Foundry	
3	1	Lamp cover, cast aluminum	Piedmont Foundry	
4	1	Glass prism	Karl Lambrecht, Chicago	
5	1	Prism mounting flange	Shop	
6	1	Phototube A	R.C.A.	929
7	2	Octal socket	Amphenol	59-355
8	1	Phototube A, lens tube	Shop	
9	1	Photo tube A, mounting bracket	Shop	
10	1	Phototube B	R.C.A.	929

Mark	No. required	Description	Manufacturer	Mfg. part no.
11	1	Phototube B, lens tube	Shop	
12	1	Phototube B, mounting bracket	Shop	
13	1	Phototube B, cover	Shop	
14	1	Lamp, 6–8 v., prefocused	G.E.	1763
15	1	Lamp bracket	Shop	
16	1	Projection lens tube assembly	Shop	
17	1	Glass platen	Karl Lambrecht, Chicago	
18	1	Loading plate	Shop	
19	1	Rubber diaphragm $^{1}/_{16}$ by $3^{11}/_{16}$ in. diam.	Garlock	
20	1	Diaphragm retaining flange	Shop	
21	1	Loading table	Shop	
22	1	Table elevating screw	Shop	
23	1	Table support	Shop	
24	1	Table guide screw	Shop	
25	1	Bevel gear and pinion	Boston	L155B
26	1	Bevel gear bushing	Shop	
27	1	Table support yoke	Shop	
28	1	Table raising handwheel	Shop	
29	1	Table raising shaft	Shop	
30	1	Table raising shaft bearing	Shop	
31	1	Table raising shaft bearing	Shop	
32	1	Set collar	Shop	
33	1	Prism support plate	Shop	
34	4	Support posts	Shop	
35	1	Hydraulic pump assembly	Shop	
36	1	Hydraulic pump handle	Shop	
37	1	Hydraulic pump shaft	Shop	
38	1	Hydraulic pump link	Shop	
39	1	Hydraulic pump shaft bearing	Shop	
40	1	Hydraulic pump shaft bearing	Shop	
41	1	Hydraulic pump set collar, stop	Shop	
42	1	Release knob shaft and bearing	Shop	
43	2	Fuseholders	Littlefuse	342001
44	2	Fuses, 2 amp., $1^{1}/_{4}$ by $^{1}/_{4}$ in.	Littlefuse	AGC
45	1	Power switch, DPST, 6 amp.	C-H	8360K7
46	1	Function switch, 6-pole 5-position	Mallory	181C
47	1	Timer, reset, 120 sec.	Cramer	RE120S
48	1	Pilot light lens cap	Allied Radio	52E445
49	1	Indicator dial assembly	Shop	
50	1	Pressure gage 0–1000 p.s.i., $3^{1}/_{2}$ in.	Marsh	Type 10FM
51	4	Supporting feet	Shop	
52	1	Dial drive gear, 128T, 32P.	Boston	H32128
53	1	Balancing motor, 27 N.L.R.P.M.	Brown	76750-3
54	1	Balancing motor mounting plate	Shop	
55	1	Helipot, 10K, 3 turns	Beckman	10KCZ
56	1	Terminal strip mounting bracket	Shop	
57	1	Helipot drive gear, 36T, 32P.	Boston	G-176
58	1	Electronik balancing unit	Brown	356358-1
59	1	Viewing port cover	Shop	
60	1	Bottom cover plate	Shop	
61	1	Back cover plate	Shop	
62	1	Multipot, 50 K	Ford Eng. Co.	50K-NL
63	1	Multipot, 20 K	Ford Eng. Co.	20K-NL
64	2	Multipot knobs	Allied Radio	55HO35
65	1	Function switch knob	Allied Radio	55HO90
66	1	Pressure release knob	Allied Radio	55HO90
67	1	Carbon resistor 2.2 meg. 1 w.	IRC	Type BTA
68	1	Carbon resistor 47 K, 1 w.	IRC	Type BTA
69	1	Carbon resistor 22 ohm, 2 w.	IRC	Type BTB
70	1	Capacitor 100 m.f.d. 150v.	Mallory	FP116
71	1	Rectifier, selenium, 65 ma.	Sarkes-Tarzian	Model 65
72	1	Transformer 117 v/25.2 v., 1 amp.	Stancor	P6469
73	1	Transformer 117 v./5 v., 8 amp.	Thordarson	T21FO4
74	1	Terminal strip, 2	Jones	2-141
75	2	Terminal strip, 6	Jones	6-141
76	2	Terminal strip, 10	Jones	10-141
77	3	Cable bushings	Shop	
78	1	Electronic equipment panel	Shop	
79	1	"O" ring (belt)	Parker	6227-36
80	4	Achromat lens, 34 by 65 mm. F.L.	Edmund Scientific Co.	
81	1	Double convex lens, 29 by 26 mm. F.L.	Edmund Scientific Co.	
82	1	Thumb nut for panel	Shop	
83	1	Lucite standardizing knobs cover	Shop	
84	1	Cable bushing block	Shop	
85	1	Prism mask, black micarta	Shop	
86	1	Carbon resistor 15 K, 1 w.	IRC	Type BTA
87	1	Carbon resistor 39 K, 1 w.	IRC	Type BTA
88	1	"Histoslide" camera body	Histoslide Co.	
89	1	"Histoslide" camera front	Histoslide Co.	
90	1	"Histoslide" camera mounting bar	Histoslide Co.	
91	1	Thumb screw, $^{6}/_{32}$ by $^{3}/_{4}$ in.	Shop	
92	1	Camera extension tube	Shop	
93	1	Shutter release bar	Shop	
94	1	Lens 2 in. F/3.5 in No. 0 Alphax shutter	Wollensak Optical Co.	
95	1	Camera mounting bracket	Shop	

Performance of Paper Machine Wet Felts. III

Experimental Plugging of Felt Strips in the Laboratory

R. F. DRESCHER and CLYDE M. CHRISTENSEN

The plugging of felts was studied experimentally by means of a machine which circulated strips of felt continuously and through wringer rolls. Various materials, such as rosin, clay, wool hydrolysate and starch were tested as plugging agents alone and in combination. In every test replicate strips were used, one of which circulated through the liquid containing size or filler to which bacteria had been added, the other through liquid with size or filler to which BSM-11 were added to eliminate bacteria, fungi, and other microorganisms. Rosin, clay, wool hydrolysates, rosin and clay combined, and starch caused plugging in decreasing order. The use of BSM-11 reduced the amount of plugging by all materials except starch from 30 to 50%. It seems that bacteria contribute very significantly to plugging of felts in use, either by their own mass or by causing various additives to accumulate in the felts. Fungi, principally species of *Aspergillus* and *Penicillium*, were isolated in some numbers from laboratory felts and from commercial felts while still on the machine or freshly removed from the machine. These fungi grew moderately vigorously in felts stored wet in the laboratory. It seems probable that at times mold mycelium might develop in sufficient amounts in commercial felts to contribute significantly to plugging.

THE principal goals of the present work were to determine experimentally the amount of plugging in paper mill felts caused by such additives as sizing and fillers with and without bacteria. While the conditions under which the tests were made do not duplicate those in paper mills, it was thought that the laboratory tests probably approximated some of the major factors that influence plugging of felts in actual use. As a secondary study, the role of fungi in plugging felts was investigated. The principal goals were to determine the kinds of molds involved, their prevalence, and the manner by which molds caused plugging.

LITERATURE REVIEW

Race (*6*) showed that bacteria are an important agent of decay or deterioration of felts in use, but he did not discuss the role that bacteria might play in the plugging of felts.

Buckman (*2*) suggested that bacteria might be involved in reducing the water-removing capacity of felts. He observed that paper mills which controlled slime formation in the milling system obtained a more effective and more uniform action from wet felts. Embedded sections made from plugged felts showed in many instances that the spaces between the fibers were occupied by foreign material which presumably lowered the water-removing capacity of the felts.

French (*4*) investigated felts plugged in actual practice under a wide range of conditions and concluded that: (1) there was no consistent correlation between plugging and the amount of size or filler added to the pulp; (2) scales removed from the wool appeared to comprise the major portion of deposits from some mills; (3) bacteria could increase plugging even though they did not contribute much bulk to the deposits; (4) wood fibers or fragments of them do not accumulate in wool felts in sufficient quantity to be a factor in plugging.

French suggested that materials such as filler and size are held in the felt by bonding agents consisting of bacteria or wool scales, or combinations of both. Wool scales might be removed from the fibers by chemical, mechanical, or bacterial actions, and the wool scales themselves could add appreciably to the overall plugging.

MATERIALS AND METHODS

Wringer-Roller Machine

The present tests were made almost exclusively with the machine designed and described by French (*4*). Strips of felt 4 in. wide were circulated as an endless belt around a roller in water at the bottom and between two rollers at the top. The machine had two tanks; usually one of these was used as a control and contained the materials to be tested plus a bactericide and fungicide, while to the other, bacteria were added to the materials to be tested for their plugging effects. The bactericide and fungicide commonly used was BSM-11,* in an amount to give a 0.1% solution in the container of the machine. The machine was allowed to run intermittently for 15-min. intervals for a total running time of $^1/_2$ hr. per hr. The length of time that the felt samples were tested on the machine is given in Tables I, II, and III. The machine is shown in Fig. 1.

Felt samples

Samples of new felts were cut into strips approximately 4 in. wide and 22 in. long and were soaked in water, threaded through the rollers, and the ends sewed together by hand. Two kinds of felt were used. One felt was relatively light and not very thick. It was a sample taken from a tanned wet felt made for the first press section of a fourdrinier machine. The mill produces fine paper such as bond and parchment. The other felt was heavier and had more dense nap. It was a sample taken from an untanned wet felt which was also made for the first press section of a fourdrinier machine. The mill manufactures book cover and rotogravure. Both felts were products of the Kenwood mills, Rensselaer, N. Y.

It was thought that different kinds of felts might

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* BSM-11, a product of Buckman Laboratories, Inc., is a combination of 10% phenylmercuric acetate, 50% potassium 2,4,6-trichlorophenate, and 40% inert ingredients.

Table I. Effect of Various Materials Added to Water on the Plugging of Felts with and Without Bactericide and Fungicide—Test I—Brown Felts.

Material added per l. of water		Length of time in days that felt was fun	Average water passage time in minutes and seconds	Microscopic plugging of interfiber area in per cent
Kind	Amount			
Clay Bacteria	13 g.	16	1:54	15-20
Clay BSM-11	13 g.	16	1:12	5–10
Felt scales	(From 10 g. wool)	9	0:33	0–10
Bacteria Felt scales	(From 10 g. of wool)	9	0:31	0–10
BSM-11	6 ml.			
Wool hydrolysate Bacteria	2 g.	6	0:37	0–10
Wool hydrolysate BSM-11	2 g. 6 ml.	6	0:33	0–10
Rosin Bacteria	0.3 g.	10	0:33	0–10
Rosin BSM-11	0.3 g. 6 ml.	10	0:31	0–10
Starch Bacteria	9 g.	8	0:34	0–10
Starch BSM-11	9 g. 6 ml.	8	0:33	0–10
Time required for water passage of new felts	New unused brown felt		0:30	
	New unused Kenwood felt		0:56	

plug differently and that by testing heavy and light felts a better evaluation of plugging might be obtained.

Determination of Amount of Plugging

The amount of plugging was determined by sectioning and staining small portions of the felt and examining them microscopically (*2*, *4*), and by determining the rate at which a given amount of water would pass through a given area of felt (*4*). New, unused pieces of felt served as controls.

While examining the data obtained by French (*4*) it was observed that felts which had a normal life (16 to 30 days) also had a water passage value of 4 min. or less. On this basis the water passage time of 4 min. was used as a standard; those felts requiring more than 4 min. for water passage were considered plugged, felts requiring less than 4 min. were not considered to be plugged sufficiently to be unsatisfactory.

Materials Tested

Clay, rosin, starch, wool felt scales, and wool hydrolysate were used as plugging agents. Because only small amounts of wool scales were obtained by agitation in a Waring blendor, wool hydrolysates were tried as a substitute. A known amount of new wool felt was hydrolyzed in commercial hydrochloric acid for approximately 15 hr. and adjusted to pH 6. The clay and starch, in powder form, were added directly to the water. The rosin solution was prepared according to the method outlined by Sutermeister (*8*) and contained 10% rosin. The amounts of each material, or combinations thereof, used in the tests are listed in Tables I, II, and III. Typical plugging is shown in Figs. 2 and 3.

Methods Used to Determine Numbers and Kinds of Molds in Felts

Mold growth was observed in felts received from paper mills by French (*4*) and also in felts on the wringer-roller machine. Because relatively little information is available on the role that molds play in plugging felts, the following methods were used.

Culture Methods Used to Determine Kinds of Molds in Felts. Molds present in the felts were evaluated in three ways: (1) pieces of felt about $^1/_2$ in. square were cultured on agar; (2) individual fibers, separated under the microscope, and bearing mycelium, were cultured

Table II. Effect of Various Materials Added to Water on the Plugging of Felts with and Without Bactericide—Test II—Brown and Kenwood Felts

Material added per 6 l. of water		Length of time in days that felt was run	Type of felt	Average water passage time in minutes and seconds	Microscopic plugging of interfiber area in per cent
Kind	Amount				
Clay and bacteria	64.4 g.	9	Brown	1:59	15–20
			Kenwood	3:37	20–25
Clay and BSM-11	64.4 g. 6 ml.	9	Brown	1:00	0–5
			Kenwood	3:12	20–25
Wool hydrolysate and bacteria	14 g.	6	Brown	1:17	5–10
			Kenwood	2:01	15–20
Wool hydrolysate and BSM-11	14 g. 6 ml.	6	Brown	1:17	0–5
			Kenwood	1:57	0–5
Rosin and bacteria	11 g.	8	Brown	2:53	30–35
			Kenwood	5:54	50–60
Rosin and BSM-11	11 g. 6 ml.	8	Brown	1:32	5–10
			Kenwood	2:35	10–15

Table III. Effect of Various Materials Added to Water on the Plugging of Felts with and Without Bactericide—Test III—Kenwood Felts

Material added per l. of water Kind	Amount	*Length of time in days that felt was run*	*Average water passage time in minutes and seconds*
Rosin	20	13	6:26
Bacteria			
Rosin	20 g.	13	3:20
BSM-11	6 ml.		
Rosin	50 g.	13	7:30
Bacteria			
Rosin	50 g.	13	5:00
BSM-11	6 ml.		
Rosin	100 g.	13	12:20
Bacteria			
Rosin	100 g.	13	8:22
BSM-11	6 ml.		
Rosin	20 g.	14	4:09
Clay	64 g.		
Bacteria			
Rosin	20 g.	14	2:50
Clay	64 g.		
BSM-11	6 ml.		
Rosin	20 g.	14	4:45
Clay	64 g.		
Bacteria			
Rosin	20 g.	14	3:18
Clay	64 g.		
BSM-11	6 ml.		
Rosin	20 g.	No data—mechanical trouble	
Wool fibers	18 g.		
Bacteria			
Rosin	20 g.		
Wool fibers	18 g.		
BSM-11	6 ml.		

on agar drops on van Tieghem cells where they could be kept under constant observation with the high power (× 400) of the microscope; (3) felts were blendorized, diluted, and cultured as described for mold counts of grain (*1*).

Growth of Molds in Felts. It was of interest to find out whether molds could grow in new unused felts in the absence of nutritive sources which might be supplied by foreign materials in used felts, and also to determine the rate and extent of growth of molds in felts.

Strips of new Kenwood felt $2^1/_2$ by 6 in. were placed in quart jars. The jar covers were cut so that the strips were held upright by a string tied to the jar cover. Approximately 200 ml. of 0.2% glucose solution was added so that part of the felt was in the sugar solution and part in the air. The part of the felt exposed to air was inoculated with *Aspergillus* and *Penicillium* spores, singly and in mixtures. The jars were incubated at room temperature for ten days, then examined microscopically for mold growth and that portion of the felt above the nutrient solution was tested for plugging.

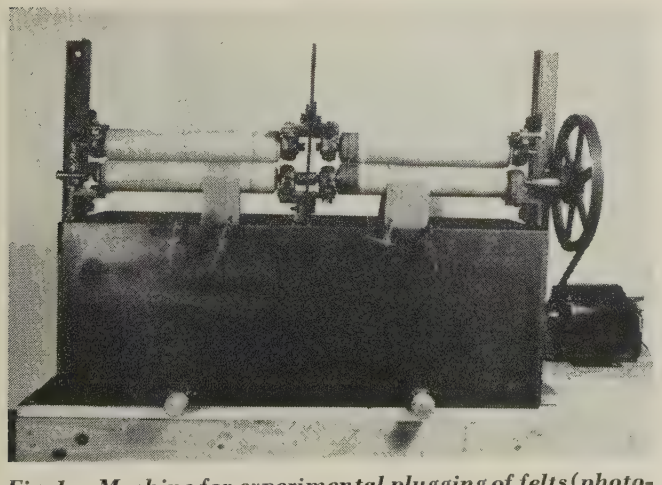

Fig. 1. Machine for experimental plugging of felts (photograph obtained from D. W. French)

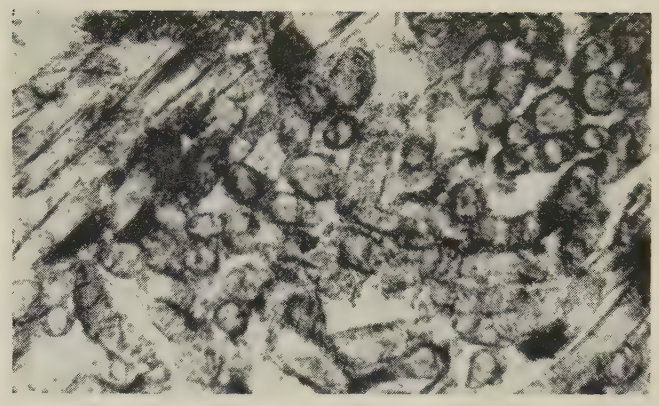

Fig. 2. Sample taken from experimental machine which contained 32 grams clay per felt and bacteria; 100×

RESULTS

The data are summarized in Tables I, II, and III. Rosin alone caused plugging, and the amount of plugging in general was proportional to the amount of rosin present. However, in the absence of bacteria, about twice as much rosin was required to produce an equivalent amount of plugging as when bacteria were present. When a relatively small amount of rosin was used, the presence of bacteria increased plugging, as measured by water passage, about 300% as indicated in Table III. The use of a bactericide and fungicide effectively reduced the plugging 30 to 50%.

Clay alone caused relatively slight plugging, and doubling the amount of clay in suspension did not materially increase plugging. However, it was found that the Kenwood felt, which is heavier than the brown felt, became more extensively plugged than the lightweight felt under the same conditions (Table II). Clay plus bacteria caused more plugging than clay without bacteria. In general, those felt samples which had been exposed to bacteria as well as clay, required an average of 33% more time for water passage than did those samples not exposed to bacteria.

Wool scales and wool hydrolysates alone or in combination with bacteria did not cause significant plugging (a water passage time of 4 min. or more). However, on the basis of comparable amounts of plugging material available per felt, hydrolyzed wool caused as much

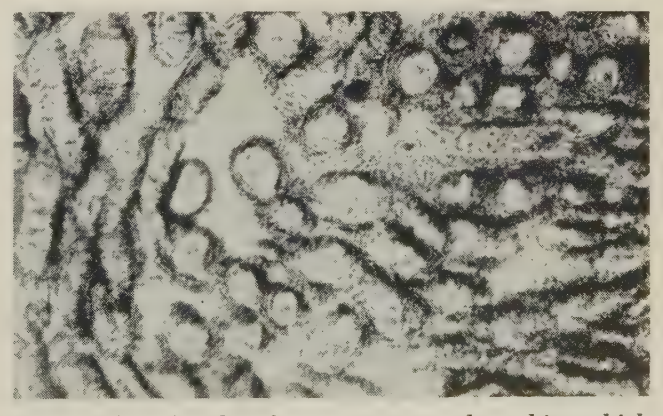

Fig. 3. Sample taken from experimental machine which contained 25 grams rosin per felt and bacteria; 100×

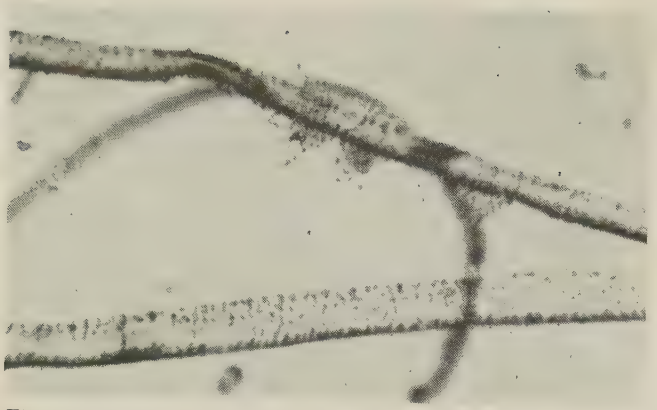

Fig. 4. Sample taken from experimental machine showing initial mycelial growth from wool fiber; 100×

plugging as did clay, and it may well be, as French (*4*) suggested, that wool scales are of some considerable significance in plugging.

Starch is often used in the manufacture of paper, so it was tried as a plugging agent. Nine grams of solubilized cornstarch per felt were used per container and at the end of 8 days the plugging was negligible regardless of the presence of bacteria or bactericide and fungicide. Because starch caused much less plugging than did other materials tried at comparable rates, it was not tested further.

Combinations of clay and rosin with and without a bactericide and fungicide were tried since it was thought that combinations of materials might cause more plugging than each alone.

In general, it was found that the plugging caused by a combination of clay and rosin was approximately one-half as much as the sum of plugging caused by each material singly. This may or may not be due to the design of the machine. The combination of bacteria with clay and rosin plugged felts approximately one and one-half times more than did the combination of clay, rosin, and bactericide.

The combination of chopped-up wool fiber and rosin with and without a bactericide and fungicide was tried but fouled the machine bearings so extensively that the rollers would not turn, and the tests were discontinued before data on plugging were obtainable.

Fungi as Possible Contributors to Plugging

It is known that fungi can grow in and deteriorate wool (*6, 9*), and that they also may be involved in slime formation (*5, 7*). However, little or no reference has been made to the role of fungi in plugging felts. Some used felts sent from paper mills to French (*4*) for examination were covered and sometimes bound together by mold mycelium, but because these felts were in transit for several days, he could not be sure whether the molds actually grew in felts in use or were a result of chance contamination after removal from the machine. Because microscopic examination of experimentally plugged felts revealed the presence of fungus mycelium and spores, it was of interest to find out what kinds of molds were growing in the felts and also to determine quantitatively the amount of fungus mycelium and spores present.

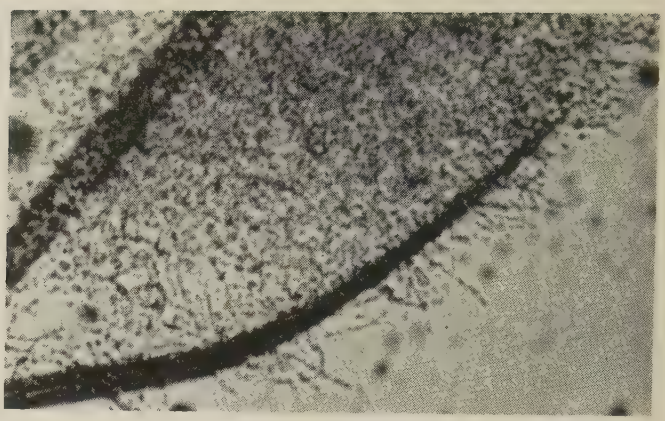

Fig. 6. Sample taken from experimental machine showing the extent of plugging caused by growth of fungi; entire mass is mycelium and spores; 100×

EXPERIMENTAL RESULTS

Culture Methods Used to Determine the Kinds of Molds Present in Felts

From each of three felts plugged by the wringer-roller machine, 25 pieces of felt about $^1/_2$ sq. in. were cultured on potato-dextrose agar and the kinds of molds isolated were: *Aspergillus glaucus, Aspergillus niger, Penicillium* and *Alternaria* species in approximately equal amounts. Samples from five commercially used felts were cultured in plates containing malt salt agar (*3*), ten pieces of felt per plate with two replications per sample. The percentage of molds fruiting on the felt pieces was: *Penicillium*—67, *Aspergillus glaucus*—16, *Aspergillus flavus*—2, and *Aspergillus niger*—1.

In order to be certain that the molds isolated were not a result of chance contamination, 50 fragments of fibers were cultured from five felts as they were being

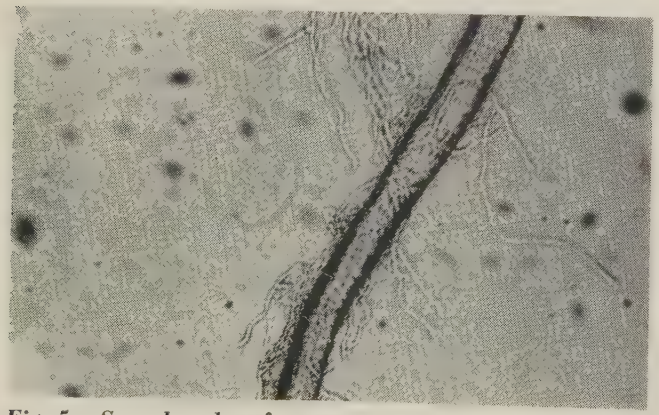

Fig. 5. Sample taken from experimental machine showing more extensive mycelial growth; 100×

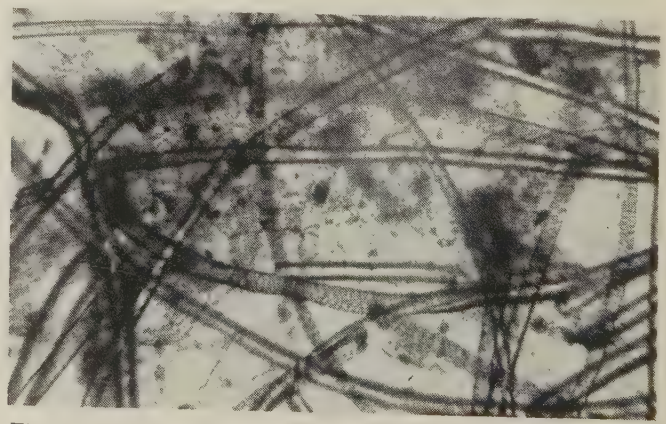

Fig. 7. Sample taken from new unused felt inoculated with Penicillium; *100×*

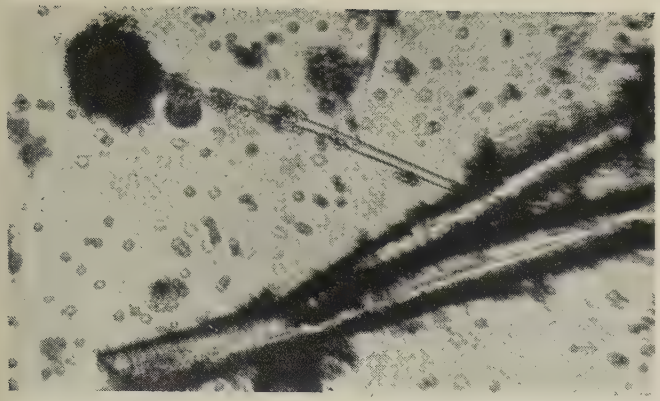

Fig. 8. Sample taken from a new unused felt inoculated with Aspergillus glaucus; *typical morphology of the fungus as shown above was never observed in commercially used felts, presumably because of disfigurement under mill conditions; 100×*

tested on the wringer-roller machine on van Tieghem cells, and the fungi obtained were: *Penicillium* species—19, *Aspergillus glaucus*—17, *Aspergillus niger*—6, *Aspergillus flavus*—5, unknown molds—2, *Alternaria* species-1, and ten isolates were contaminated with bacteria, and no data on molds were obtained.

Various stages of growth of molds on wool fibers are shown in Fig. 4, 5, and 6. The photomicrographs were taken of molds isolated from the test felts by the previously described method. Figure 6 is especially interesting because it shows the amount of bulk that mold growth can contribute and is offered as evidence that molds may be important in causing plugging. In comparison with the other photomicrographs, the amount of bulk caused by molds is not only greater than the amount caused by bacteria, but also suggests that mold growth provides more surface to which papermaking agents can adhere.

Quantitative Methods Used to Determine the Number of Molds in Felts

Seven felts were assayed to determine the mold population, and the data are summarized in Table IV. The experimentally plugged felt was assayed first and the total mold population was 141,000 molds per gram. Six different felts from paper mills were similarly cultured, the assays in each case being made within hours after the felt was removed from the machine. The mold count of all six felts when averaged was about 15,000.

A piece of new unused felt $1^1/_4$ in. sq. weighs approximately 1 gram. Because the quantitative plate method is used mostly to determine the number of spores present, it would seem unlikely that 8000 to 30,000 spores per sq. in. of felt would cause a significant amount of plugging. It should be pointed out, however, that if the molds are present mainly as mycelium—as the microscopic examination indicated was the case—a count of 10,000 to 30,000 per gram might involve a considerable bulk of mycelium, at least sufficient to cause or contribute to plugging.

Petri plates were exposed in a paper mill near the wet press section and also near the beater tanks. The purpose of exposing the plates was to determine whether the same kinds of molds were present in the air of the paper mill as were found and identified in the felts, since it was thought that possibly felts assayed in the laboratory might have been contaminated with molds commonly found in the laboratory. The plates contained malt-salt agar and were exposed for 12 min. A total of ten plates were exposed and the molds identified were: *Penicillium*, *Aspergillus glaucus*, *Aspergillus candidus*, *Aspergillus flavus*, *Aspergillus niger*, *Cladosporium*, and *Alternaria* in decreasing order. There were approximately ten colonies per plate.

Growth of Molds in Felts

Two felts were inoculated with *Penicillium*, two felts with *Aspergillus glaucus*, and a fifth felt with a mixture of *Aspergillus glaucus*, *Aspergillus flavus*, and *Aspergillus niger*. Two felts were not inoculated with spores, and all were incubated at room temperature.

The felts were examined 10 days after inoculation and the following observations were made. *Aspergillus glaucus* did not grow as well as *Penicillium*, and in each case the growth of the fungus was correlated with the development of reddish coloration of the felts. In a period of 10 days *Penicillium* had overgrown the entire surface of the portion of the felt not submerged in water. When the felts were examined under the microscope, extensive mycelium was observed, and in spots the mycelium was wefted. Figure 7 shows the growth of *Penicillium* in new unused felts while Fig. 8 shows *Aspergillus glaucus* fruiting on felt fibers. The water passage time required for felts invaded by *Penicillium* was 2:24 min., by *Aspergillus glaucus* 2:05 min., and by a mixture of *Aspergillus glaucus*, *Aspergillus flavus*, and *Aspergillus niger* 2:21 min. The water passage time of the check felts was 1:33 min. These data would suggest that although molds by themselves did not cause extensive plugging in these tests, they were a more effective plugging agent than bacteria alone. No tests were made of molds plus fillers or sizes.

SUMMARY

1. Rosin caused more plugging than any other single material tested. Clay and wool hydrolyzates caused

Table IV. Molds per Gram Found in Felts

Types of felt	*Time*	*Type of medium used*	*Number of replications*	*Total molds per gram*	Asp. glaucus	Asp. niger	Penicillium
1. Experimentally plugged felt	August, 1952	Malt-salt	6	141,000			
2. Used paper mill felt (after acid treatment)	September, 1952	(a) Malt-salt	6	19,000			
		(b) Acid P.D.A.	5	33,000			
		(c) Malt agar	5	36,000			
3. Paper mill felt no. 1	April, 1953	Malt-salt	4	9,250	3250		6000
4. Paper mill felt no. 2	April, 1953	Malt-salt	4	1,400	700		700
5. Paper mill felt no. 3	April, 1953	Malt-salt	4	6,200	2750	2750	700
6. Paper mill felt (topfelt)	May, 1953	Malt-salt	3	8,000	2000		6000
7. Paper mill felt (bottom)	May, 1953	Malt-salt	3	8,500	2000		6500

less plugging than rosin, and wool scales and starch caused the least amount.

2. Rosin and clay combined caused less plugging than rosin alone.

3. Bacteria appear to play a very important role in plugging, as their presence always increased the amount over that caused by the filler or size alone, and in some cases the increase was approximately 300%.

4. The bactericide and fungicide, BSM-11, appeared to reduce considerably the plugging caused or contributed to by bacteria.

5. Molds such as *Penicillium* and *Aspergillus* were isolated commonly from laboratory felts and from used commercial felts. These molds probably are not present in sufficient amounts to cause severe plugging by themselves, but they might contribute significantly to plugging.

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Apparatus for Measurement of the Water Vapor Permeability of Packaging Materials

P. P. TEMPLIN, J. J. KAUFMAN, and R. G. CAPELL

A small humidity cabinet employing acid solutions for controlling humidity and designed for operation in a constant temperature room has been shown to give satisfactory results from the standpoint of reproducibility and adaptability to TAPPI Standard T 464 m-45 test conditions. It is good for routine testing and also for research purposes where one may wish to make water vapor transmission measurements over a wide range of temperatures and humidities.

A PORTABLE constant humidity cabinet, designed for carrying out 24 simultaneous determinations of the water vapor permeability of sheet materials under TAPPI Standard T 464 m-45 (*1*) conditions at 100°F. and a relative humidity of 90%, has been tested and found to give excellent results. The cabinet is placed in a larger, walk-in, electrically heated room controlled at the proper temperature, and the humidity in the cabinet is controlled very precisely by the use of a sulphuric acid solution of adjusted concentration. It is adaptable to operation under a wide range of temperatures, limited only by the range of controlled room temperatures available. By changing acid concentrations, the humidity may be readily varied from saturation to near desiccating conditions.

Figure 1 is a photograph of the front of the constant humidity cabinet. Figure 2 is a cut-away view, showing an arrangement of the inverted test dishes on an expanded metal shelf with the acid tray beneath and location of the air-circulating fans. Figure 3 is a cross-section of the standard test dish used.

PROCEDURE

The procedures for preparation of sheet materials to be tested, i.e., cutting, filling, sealing, and weighing the test dishes are the same as described in T 464 m-45. The dishes are placed in the humidity cabinet from the top since the metal cover is held in place only by its own weight and is removable simply by lifting. The acid solution is readily changed by removing the wing nuts, see Fig. 1, and sliding the acid tray forward and out from beneath the metal shelf.

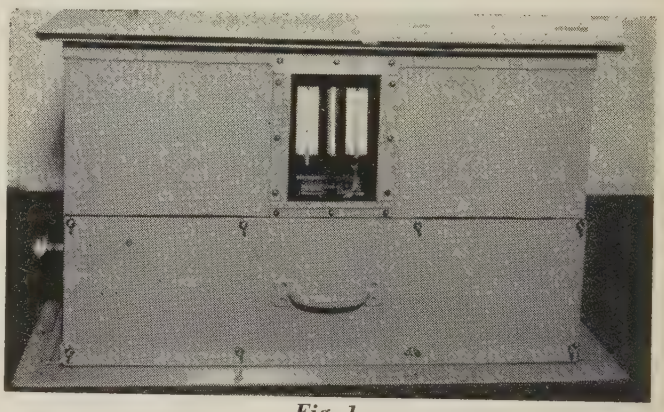

Fig. 1

Sulphuric acid solutions are excellent for control of humidity in such a system, because of their high capacity for absorption or release of moisture without much change in vapor pressure and because of their relative insensitivity to small changes in temperatures (*2*).

RESULTS

In Table I is shown the reproducibility obtainable

Table I. Reproducibility

	Bread wrap paper	*Permeabilities; grams of water/sq. meter/24 hr. at 100°F. and 90% R.H.*			*Average*
A	Run 1	46.4	42.8	40.6	43.4 ± 1.4
	Run 2	44.3	44.0	42.8	43.7 ± 0.6
B	Run 1	4.90	3.55	3.08	3.84 ± 0.70
	Run 2	5.85	7.06	3.73	5.55 ± 1.21
C	Run 1	30.2	25.3	26.4	27.3 ± 1.9
	Run 2	28.6	28.4	28.0	28.3 ± 0.2
D	Run 1	29.2	28.8	29.2	29.1 ± 0.2
	Run 2	27.8	28.4	28.4	28.2 ± 0.3

P. R. TEMPLIN, J. J. KAUFMAN, and R. G. CAPELL, Multiple Fellowship of Gulf Research & Development Co., Mellon Institute, Pittsburgh, Pa.

Table II. Effect of Air Circulation on Permeability Measurements

Bread wrap paper		*Individual transmission rates; grams of water/sq. meter/24 hr.*						*Average transmission*	*Standard deviation*
A	With circulation	43.0	45.2	44.0	46.2	43.5	...	44.1	1.0
	Without circulation	46.4	42.8	40.6	44.3	44.0	42.8	43.5	1.4
B	With circulation	1.95	3.84	3.64	3.79	4.24	3.66	3.25	0.5
	Without circulation	4.90	3.55	3.08	5.85	7.06	3.73	4.69	1.2
C	With circulation	25.0	26.3	26.6	27.4	25.9	24.6	25.9	0.8
	Without circulation	30.2	25.3	26.4	28.6	28.4	28.0	27.8	1.3
D	With circulation	26.6	29.6	23.2	30.8	30.7	29.9	28.5	2.4
	Without circulation	29.2	28.8	29.2	27.8	28.4	28.4	28.6	0.4

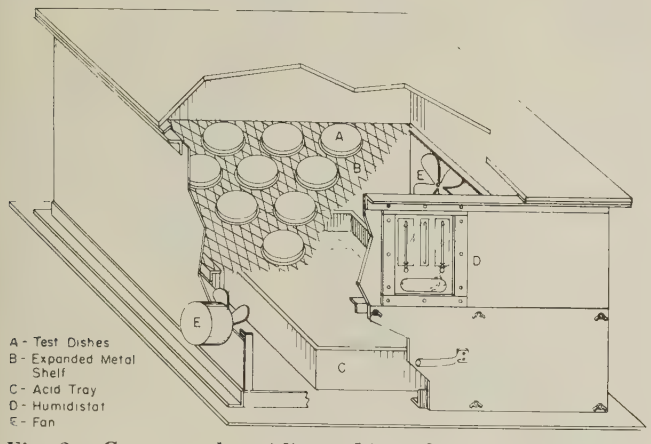

Fig. 2. Constant humidity cabinet for water vapor permeability test

with the new cabinet; the figures indicate that at permeabilities above 25 grams per sq. meter per 24 hr. the precision of measurement is less than ±10%. At permeabilities below 10, reproducibility is poorer but still within the TAPPI Standard. Table II indicates the effect of operation of the cabinet with and without forced air circulation over the solution. It will be noted that the effect of circulation is relatively small. However, it is believed that for best results, after a new batch of samples has been charged to the unit it is best to run the circulating fans for a short time in order to speed up the attainment of equilibrium conditions. In Table III are given data on the water vapor permeability of 130° melting point paraffin containing polyisobutylene and polyethylene. Apparently as the molecular weight of polyisobutylene increases, the permeability of its blend in wax decreases. Molecular weight does not seem to affect the permeability of polyethylene blends as in the case of polyisobutylene. All of the polyethylene blends and most of the polyisobutylene blends were more permeable than uncompounded wax. Table IV contains a few permeabilities obtained with this equipment, for a variety of sheet materials ranging in permeability from about 0.1 to 50.

Table V shows the effect on permeability of increasing the weight of wax coating. At a deposition of wax of about 13 to 18 lb. per ream, permeability reaches a minimum. Wax depositions above this level seem to have little additional effect on the transmission rate.

Table III. Effect of Additives Upon Water Vapor Permeability

Additive	*Molecular weight*	*% Conc.*	*Wax deposition,[a] grams/sq. ft.*	*Water vapor permeability, grams H_2O/ sq. meter/24 hr.*
Paraffin only[b]	...	..	2.0	8.3
Polyisobutylene				
LM-H	17,000	5	2.0	40.0
B-60	55,000	5	2.0	25.4
B-80	70,000	5	2.0	12.0
B-100	90,000	5	2.0	11.3
B-120	108,000	5	2.0	6.1
Polyethylene				
DXL-1	1,000	5	2.0	31.0
DXL-4	4,000	5	2.0	44.3
DXL-7	7,000	5	2.0	30.5
DXL-12	12,000	5	2.0	42.8
DYNH	20,000	5	2.0	30.0

[a] On 25-lb. sulphite paper.
[b] 130°F., EMP.

Table IV. Permeability of Various Sheet Materials

Material	*Wax deposition, grams/sq. ft.*	*Thickness, in.*	*Water vapor permeability, grams/sq. meter/24 hr. (at 100°F. and 90% R.H.)*
Waxed glassine	2.0	...	4.40
Waxed kraft	2.78	0.035	25.8
Polyethylene	...	0.0015	13.3
Cellophane, MST-51	...	0.001	6.48
Aluminum foil	...	0.0005	0.12
GRS	...	0.0035	49.1

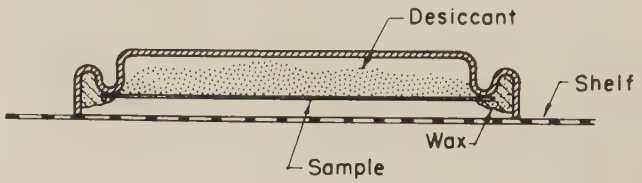

Fig. 3 Cross section of test dish

Table V. Dependency of Permeability on Weight of Paraffin Coating

Deposition in pounds of paraffin per ream[a] of 25-lb. sulphite bread wrap paper	*Permeability, Grams H_2O/24 hr./sq. meter*	*Grams H_2O/24 hr./100 sq. in.[b]*
7.91	49.6	3.2
7.91	46.0	3.0
8.29	34.6	2.2
8.23	27.2	1.7
8.80	22.5	1.5
8.86	17.3	1.1
9.37	15.5	1.0
9.68	12.8	0.8
10.82	9.4	0.6
13.67	8.0	0.5
15.57	7.5	0.5
17.34	6.7	0.4
19.00	8.1	0.8
33.36	8.9	0.6
35.00	8.5	0.5

[a] 480 sheets, 24 × 36 (2880 sq. ft.).
[b] The WVP literature contains numerous instances where data are reported using 100 sq. in. surface area. Most of the data so reported were obtained using the G.F.M.V.T. method (General Foods Moisture Vapor Transmission Tests, Anon., *Modern Packaging* 16, No. 3: 78, 80, 82 (Nov., 1942)).

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The authors wish to acknowledge the assistance of John A. Stewart who designed the test cabinet described in this article and ran some of the early tests.

Field Investigation of Corrosion in Alkaline Pulping Equipment

C. B. CHRISTIANSEN and J. B. LATHROP

Two distinct forces which combine to cause digester corrosion were found in Canadian mills by a task force of specialists which investigated the problem of corrosion of alkaline pulping equipment by a careful study in each mill of over 100 variables. One set of forces which tends to localize and aggravate the corrosive attack and which determines the many corrosion patterns found in digesters has been identified. A chemical hypothesis has been developed which appears to explain the large differences from mill to mill in the rate at which the other set of forces causes corrosion to proceed in a broad areal attack over the exposed surfaces of a digester. This intensive study of the complex problem of corrosion has resulted in a number of recommendations for extending the service life of alkaline pulping equipment.

PART I—BY C. B. CHRISTIANSEN

THAT laboratory work could only be regarded as a premature and rather empirical approach because of the complexity of the problem, involving as it does a host of interrelated variables (some of which were as yet even unknown), was clearly recognized by the Alkaline Pulping Committee of the Technical Section, Canadian Pulp and Paper Association, when it recommended, in 1950, that the Institute undertake an intensive investigation in each mill so as to seek out the causes of corrosion. At that time everywhere in the world there were many conflicting theories as to the causes of corrosion. This confusion was increased greatly by several unexpected early failures of corrosion-resistant alloy steels that had appeared most promising when specimens had withstood the attack during trial periods in mill digesters. It was obvious that, before a sound experimental program aimed at finding solutions to the problem could even be conceived, every shred of physical, chemical, operating, metallurgical, and corrosion information available in the mills would have to be collected, sorted, and analyzed thoroughly. Only then would there be any hope of singling out those variables which have the more marked influence on corrosion and of determining the effects of changes in operating practices over the years. A much less costly experimental program would then be required than if an effort were to be made to evaluate experimentally *all* variables at the laboratory scale.

Hence, the objectives of this project have been: (1) to identify the variables in the problem and to find which of the many suspected or known variables involved has or have the greatest influence on corrosion, (2) to recommend remedial measures as they became apparent, and (3) from a thorough analysis of the data collected, to design carefully whatever subsequent experimental program aimed at finding a complete solution might be deemed desirable.

In that this project was initiated at the request of the Alkaline Pulping Committee of the Technical Section, Canadian Pulp and Paper Association, a progress report summarizing the work done, the findings, and the recommendations was given at the 1954 annual meeting of the Technical Section held in January. This same summary report is being given again at this annual meeting of TAPPI at the specific request of the Digester Corrosion Subcommittee of TAPPI.

Procedure

The unique feature of the method adopted for this project by the Canadian industry was the employment of a single, full-time task force of specialists to investigate conditions and to collect all available data in each mill on a uniform, comparable basis.

This task force, free of mill responsibilities, was able to devote its full attention to this investigation, to observe and relate to mill conditions the variations in corrosion from mill to mill, and to uncover factors that might not have been obvious to mill personnel since only the one example of their own mill would normally be available to them for study.

The data collected during the inspection of 91 digesters and the investigation in 16 mills, together with the results of the liquor analyses and of studies on steel samples procured by the task force, have been subjected to a thorough, statistical analysis by operations research techniques.

No phase of this work could safely have been omitted because no one knew which of the many variables (some 125) might prove significant. This was foreseen by the Technical Section when it recommended that the Institute undertake an intensive investigation which would include a thorough study of liquor composition and a complete metallurgical investigation.

Findings and Recommendations

This study of the problem has made it clear for the first time that there are two sets of forces which combine to cause digester corrosion. The Institute has termed these:

1. *Primary Corrosion*—which occurs in the form of a broad areal attack over the exposed surface of a digester. It results from the interaction of steel, wood, and liquor during cooking.

2. *Secondary Corrosion*—which concentrates and aggravates the attack and determines corrosion patterns. It is influenced by scale, fabrication methods, digester design, certain operating practices, and possibly vari-

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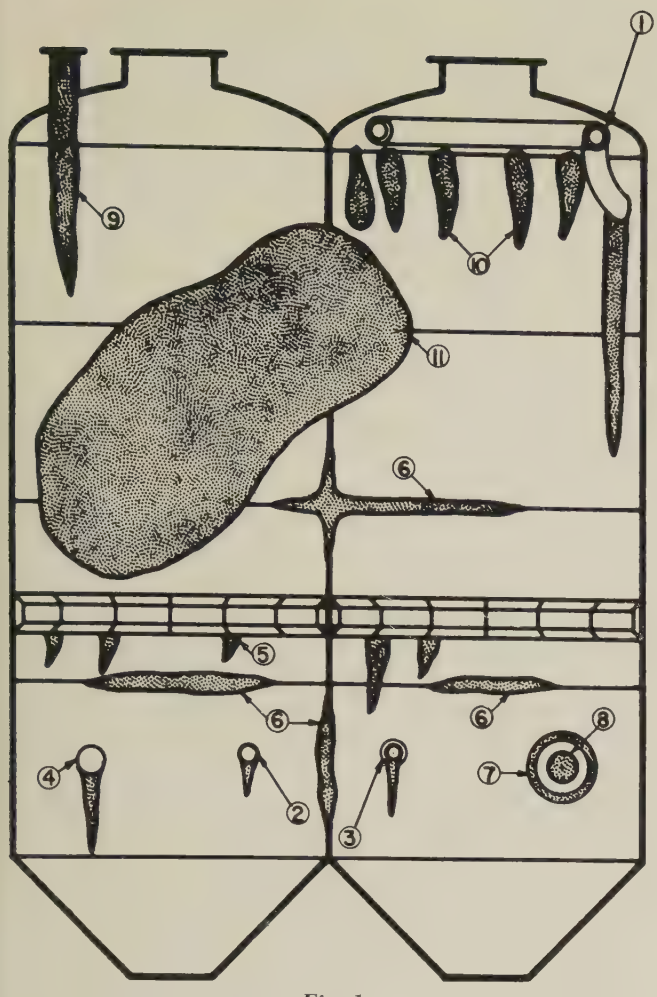


Fig. 1

Explanation of types of secondary corrosion depicted in Fig. 1: Whenever the digester design is such that stock can hang up between blows severe localized corrosion is likely to occur below the fittings concerned, for example, below: horizontal types of liquor circulation inlets (1), sample fittings (2), and thermometer elements (3); unused fittings blanked off on outside of digester (4); and junctions of certain designs of liquor strainers (5). Automatic welds on inside of digesters frequently corrode more rapidly than the adjacent plate (6). Stainless steel weld metal in carbon steel digesters is frequently undercut by corrosion (7). Cast steel fittings often become deeply pitted (8). Severe corrosion occurs when digester walls are intermittently washed by liquor that is in intimate contact with air, as for example when liquor flows down the walls under vertical liquor inlets (9), when circulated liquor impinges on walls (10), and when liquor is directed against a wall by uneven chip distribution (11).

ations in steel. Figure 1 illustrates the corrosion patterns that would be found if the various types of secondary corrosion (excluding those dependent on scale and steel uniformity) existed in one digester.

Secondary Corrosion

The serious reduction in digester life that may occur on account of secondary corrosion, many of the conditions that promote this rapid attack, and numerous remedial measures for alleviating this corrosion were described in detail in the Institute's Progress Report No. 4 to the sponsors of the project and in less detail in informal presentations at meetings of the Technical Section and of TAPPI. Some of the most important remedial measures recommended are highlighted as follows:

1. Design the digesters (particularly liquor inlets, strainers, and other fittings) so that stock does not hang up between blows. Otherwise, severe localized corrosion is likely to occur under the fittings concerned.
2. Specify that only manual welding be used on the inside of digesters.
3. Avoid the use of stainless steel liners and fittings when they must be welded to the inside shell of carbon steel digesters.
4. Do not use cast steel fittings. Specify that fittings be forged or fabricated from rolled steel plate.
5. Remove from the inside surface of digesters any mill oxide scale that still remains after digester fabrication.
6. Avoid washing of the walls with liquor that is in intimate contact with air. This occurs with certain types of filling inlets that allow the liquor to flow down the walls, with liquor distributing rings that permit impingement of the liquor on the walls and with uneven chip distribution which directs filling liquor against the wall.

In regard to the last recommendation, the task force has found that the secondary corrosion which takes place during filling frequently affects large areas and, on occasion, may reduce digester life by as much as 50% if corrective measures are not taken in time. It is certain that care should be exercised to ensure even spreading of the chips throughout the entire period of chip filling and to ensure that the filling liquor is not directed toward the wall. Also the following practices should probably be adopted so as to decrease this type of secondary corrosive attack:

1. Reduce strength of the white liquor before its addition to the digester by mixing it with the black liquor in a blending tank prior to charging.
2. Displace air from the digester during chip filling by adding steam through the bottom nozzles. Continue steaming until initial filling of chips is completed to ensure removal of as much air as possible. For reasons of safety, liquor should not be introduced into the digester until steaming is discontinued.

Other secondary factors are of less importance. For example, the direction of liquor circulation may influence the corrosion patterns but does not appreciably affect corrosion rates. Some evidence of chip and steam erosion has been observed by the project team, but in these cases the decrease in plate thickness has been negligible.

Local corrosion patterns are influenced by the presence of both mill oxide (scale formed in rolling mill) and liquor scale (scale formed from the cooking liquor). The fact that liquor scale has been found in some digesters of every mill and that fittings which extend inside the digester are practically always covered with scale suggests that *all* mill liquors contain, to some degree, the necessary scale-forming components and that complete scale coverage is primarily dependent upon conditions other than liquor composition.

Although corrosion appears to be arrested in scaled areas, nowhere has the task force found any digesters that were completely protected by scale (and to be truly effective the entire surface would have to be covered with scale).

In the digesters inspected by the task force only small areas were covered with mill oxide scale (Fe_3O_4). Studies of corrosion by other investigators have shown that rapid, galvanic corrosion of exposed areas takes place in some environments, such as sea water, when mill oxide scale is present. Although this may not occur in alkaline pulping digesters, removal of this scale before the units are placed in service appears advisable.

Investigation of Primary Corrosion

Thus far the discussion has dealt with the causes of localized attack—i.e., the factors which combine to produce a corrosion pattern. In the investigation of the causes of primary corrosion (i.e., the corrosion which tends to occur in the form of a broad areal attack), the Institute engaged the firm of Arthur D. Little, Inc., Cambridge, Mass., to study by operations research techniques the mass of data assembled by the Institute's corrosion task force. The development of an hypothesis which explains the wide variation in corrosion rates among mills is described below.

PART II—BY J. B. LATHROP

During the course of this project, the Pulp and Paper Research Institute of Canada collected a great deal of information concerning the operating, chemical, and metallurgical conditions at Canadian kraft mills, together with measurements and descriptions of corrosion conditions at those mills. The task of the operations research group of Arthur D. Little, Inc., was to interpret these data in order to derive, to the greatest extent possible, meaningful relationships between corrosion and the factors causing it.

Well over 100 factors in connection with chemicals, steels, woods, times, and temperatures of the process were candidates for consideration as potentially affecting corrosion rates. Since the number of kraft mills in Canada is relatively small it was impossible to determine by statistical means alone the degree of contribution of each of these factors to corrosion. It was necessary, therefore, to adopt an operations research approach. By this we mean, loosely, the development of quantitative hypotheses as to possible relationships between certain of the factors and corrosion rates, based upon the knowledge and opinions of chemists, metallurgists, and others with long experience in the pulp and paper field. Each of a series of such hypotheses involving only a few of the possible factors at one time would constitute, if you will, an educated guess as to the possible form of a relationship which might explain corrosion. These hypotheses, in turn, were checked against data gathered by the project task force to see if the data supported the hypothesis, rejected it, or merely told us nothing one way or the other, which was often the case.

Measures and Models of Corrosion

One of the first questions which we faced was that of

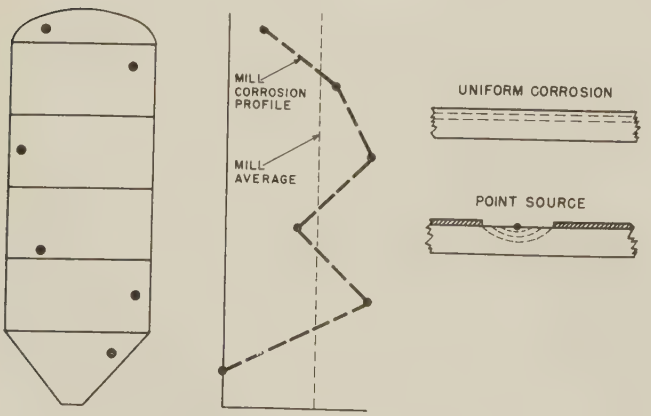


Fig. 2. Measures and models of corrosion

Fig. 3. Years of service when corrosion measured

the suitability of our data on corrosion in connection with kraft digesters as a measure of the amount of actual corrosion experienced. In most cases Audigage measures of digester thickness at the thinnest point in a large, presumably unrepairable area of corrosion in each plate of each digester had been taken. We did not have thickness measurements over a very large number of lattice points for each digester as is obtained under some systems. Also, we did not have an accurate measure of plate thickness at the time corrosion commenced, but did know the original nominal thickness of the digester plates.

The suitability of the data as a measure of corrosion depended to some extent upon the model or hypothesis of corrosion adopted as a premise. If corrosion is assumed to commence as soon as a digester is placed in service, and to attack the entire area of the digester at a uniform rate (Fig. 2) then our data are not nearly as suitable as that derived from a large number of measurements taken in the form of a lattice covering the digester. On the other hand, if corrosion is taken to commence relatively early in the service life of a digester, but at isolated points such as cracks in scale, and then to proceed outward and downward from such initial points at a uniform rate, our measure would be particularly suitable. It can be shown that, under this hypothesis, the deepest penetration in an area of primary corrosion should be proportional to the total amount of primary corrosion occurring in the plate or digester. The Institute's data also have the advantage that its measure of corrosion is independent of the amount of scale present in the digester. The fact that we did not possess an accurate determination of the initial thickness of the plates when corrosion commenced is offset by the fact that many of the digesters have been in service and exposed to corrosion for several years (Fig. 3), allowing this initial error to be spread over several years and to become insignificant. Still another advantage of the measure adopted by the Institute was that it represents the criterion on which digesters are actually condemned; large area, unrepairable corrosion, even if occurring in only a limited area of the vessel.

Our conclusion was, therefore, that the data available permitted the derivation of a suitable measure of corrosion rate, although with considerable variation to

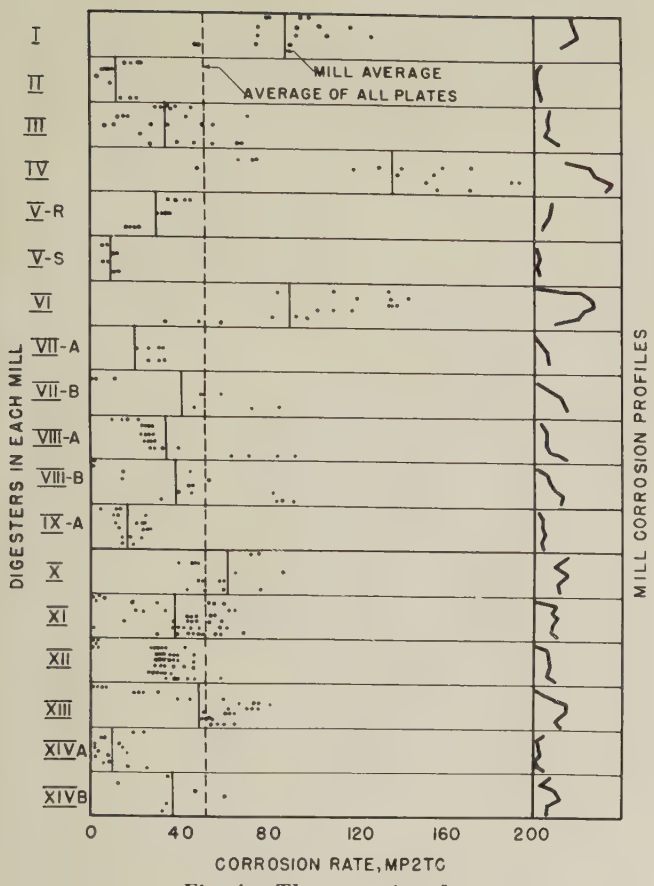


Fig. 4. The corrosion data

be expected from local conditions and measurement errors.

Method of Averaging

A problem was presented as to the method of averaging the measures of corrosion for each plate of each digester in the course of obtaining single measures to typify the corrosion rates of entire digesters or entire mills. In some cases, measures for particular plates were unobtainable. In other cases, corrosion associated with very local physical or operating conditions, the effects of which the averaging method should eliminate as much as possible, extended over two or more plates of a digester.

In order, therefore, to minimize the effects of missing measures, and of local conditions, measures for each of the digester heads in a mill were first averaged to obtain a corrosion rate typical of heads in that mill (Fig. 2). Similarly corrosion rates typical of each plate location were obtained for each mill. The composite of these plate averages comprises a "corrosion profile" taken to be typical of the mill.

The average of the points in the profile was then taken to be suitable for use as a "mill-average corrosion rate," with the effects of plate location and local conditions minimized, reflecting principally the effects of the primary interactions among wood chips, cooking liquors, and steels.

The Corrosion Data

In Fig. 4 is summarized one form of the corrosion data used. The corrosion rate is measured in terms of "mils per 2000 cooks" (MP2TC). This measure is derived as follows: change in thickness during the period of digester operation is divided by the total number of cooks made in this period (in units of 2000, since the average number of cooks made in Canadian digesters during their service life was very nearly 2000 cooks per year). Other measures were also employed for parts of the study, for example "mils per operating year" which is the change in thickness during the period of digester operation divided by the total number of days in this period (in units of 300, since the average number of days of digester operation in Canadian digesters during their service life was very nearly 300 days per year).

Along the vertical coordinate of Fig. 4 are arranged the mills participating in the survey, coded by number. In cases where, within a single mill, there were groups of digesters in service over radically different periods of time, or groups of digesters operated in radically different ways, the data for a mill were split into two groups as for VIIIA and VIIIB R means rotary digesters and S stationary.

Opposite each mill number, arrayed from top to bottom, are the individual corrosion rate measurements for the head, each plate, and the cone of the digester. The average corrosion rate for each plate position within a mill makes up the "mill corrosion profile" as sketched roughly at the right of Fig. 4. The average corrosion

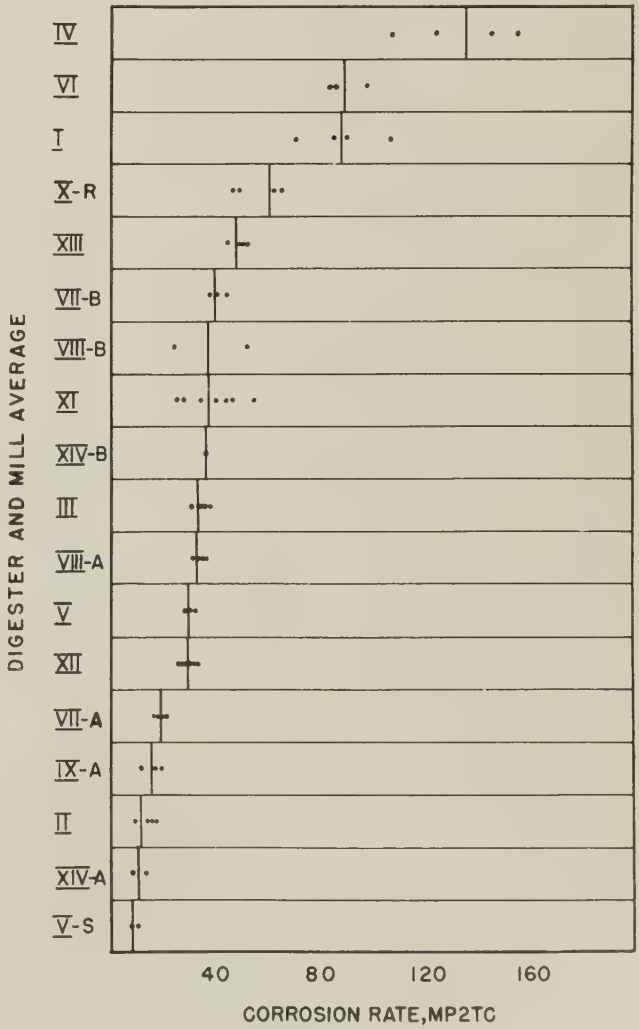


Fig. 5. Digester and mill averages

rate for all plates in all digesters of all mills and each mill-average corrosion rate are also shown.

Partition of Variation

From Fig. 4 we see that there is a great deal of variation in corrosion rates, from almost 0 to 200 MP2TC. Mill-average corrosion rates range from about 9 to about 140 MP2TC. In some mills the variation of individual plate measurements about the mill average is very large while in other mills it is much smaller.

One of the first tasks of our study was to find out, if we could, how much of this variation typically occurred within the digester, how much within the mill, and how much occurred between mills. We wanted to know how much of the variation could be due to chance, and how much could only be due to significant differences in steels, liquors and operating practices. If the variations could be explained, they would reveal a great deal about the causes of corrosion.

An analysis of the variation showed that about 28% of it appeared to be due to the existence of corrosion profiles, that is, to differences in corrosion rate from one part of a digester to another. Only 9% was due to variations around the mill corrosion profiles. This indicates that the corrosion profiles are really typical of of a mill, and that from digester to digester within a mill there is little variation from the mill profile. By far the greatest amount of the total variation, about 63%, appeared to be due to differences from mill to mill. In other words, there were highly significant differences in basic corrosion rate from one mill to another.

In Fig. 5 the mill-average corrosion rates are ranked from the lowest to the highest, and about each are shown the average rates for some digesters in the mill. The corrosion rates among mills differ by as much as a factor of 10, while within mills the digester averages cling relatively closely to the mill averages.

Causes of Variation from Mill to Mill

We then concentrated our attention on the significant differences in corrosion rate from mill to mill. They cannot be due to chance. We first tried to correlate these differences in corrosion with differences in cooking pressure from mill to mill, differences in cooking time, differences in the time at pressure, with no success. We attempted to relate these differences to differences in sulphidity, to activity, and reduction practices of the different mills, again with no results. In the course of tests of this sort, however, we did find that mill to mill corrosion rates changed along with white-to-black liquor ratios, and since these ratios were increasing with

Factors

C = corrosiveness
X = Na_2S
Y = NaOH
Z = $Na_2S_2O_3$

Complete Linear Model

$$C = A_0 + A_1X + A_2Y + A_3Z + A_4XY + A_5XZ + A_6YZ + A_7XYZ$$

Approximation

$$C = A_0 + A_1X + A_2Y + A_5XZ$$
$$= -3.6 + 0.03X + 0.11Y + 0.04XZ$$

Fig. 6. Model of Corrosion

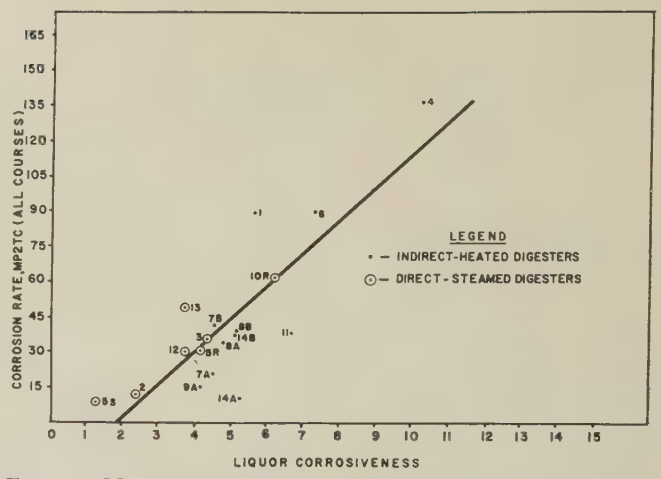


Fig. 7. Mill-average corrosion rate against liquor corrosiveness

time, this correlation appeared to explain the apparent increase in corrosion rate with time over recent years. Also, we noted that corrosion rates for direct-steamed digesters were significantly different from corrosion rates for indirect-heated digesters. These observations led us to concentrate on differences in liquors as being the most promising area in which to find explanations of the differences in corrosion rate among mills.

The Chemical Hypothesis of Corrosion

Stockman (*1*) at the Swedish Forest Products Research Laboratory had investigated in the laboratory the effects on corrosion of increasing the concentrations of individual components of sulphate cooking liquors. He found that those contributing heavily to corrosion included sodium sulphide, sodium hydroxide, and sodium thiosulphate. From the Canadian mill data alone, differences in no one of these chemical components could be correlated directly with corrosion differences from mill to mill, so we tried to find some interaction of chemical components, indicated to be important by the Swedish experiments, in a mathematical model—or hypothesis—of corrosion, and test this combined hypothesis against the Canadian data. Figure 6 lists the factors with which we were concerned. Stockman's work had indicated that corrosion increased nearly linearly with the concentration of each of the three liquor components, so a linear relationship seemed most suitable. We would like to have been able to solve, from the Swedish data, an equation such as that labelled "complete linear model." The data, however, were insufficient to obtain more than three or four terms of the complete expression. After selecting various combinations of terms and fitting the resulting equations to the data, after obtaining informed opinions as to which interactions were reasonable and which were not, and after rejecting forms of the hypothesis which did not give reasonable values in the areas of soda process liquors, we found that the equation labelled "approximation" worked best all around. It indicates that sodium sulphide and sodium hydroxide affect corrosion independently of the other components, while the importance of sodium thiosulphate is multiplied by the presence of sodium sulphide.

Later on, when we had more data available, we developed this same type of relationship from the Canadian data alone, completely independent of the

Swedish experiments, and found that this approximation worked about as well as any other. Other combinations of these factors, however, were nearly as satisfactory in indicating the relationships between corrosion and liquor corrosiveness.

Figure 7 summarizes the results of the attempt to relate liquor components and corrosiveness in order to explain mill-to-mill variations in corrosion rates. On the vertical axis are shown mill corrosion rates, again in terms of mils per 2000 cooks. The horizontal scale is of the calculated liquor corrosiveness for each mill from our hypothesis.

Data on the chemical history of mill liquors and on black-to-white ratios, year by year over the service lifetime of the digesters were available in most cases. We did not have, usually, a history of thiosulphate concentrations and were forced to estimate them on the basis of the Pulp and Paper Research Institute's detailed analysis of several sets of liquors from each mill. Liquor concentrations were averaged over the entire service periods of the digesters in deriving the over-all measure of corrosiveness for each mill.

Conclusions

Statistically, there is significantly good agreement between corrosion rates as observed, and corrosiveness, as we have measured it. The particular formula or hypothesis used here, as to how corrosion is related to corrosiveness, seems to explain about 80% of the variation in corrosion rates from mill to mill. There may be a better formula relating liquor composition to corrosiveness, i.e., one which might explain more than 80% of the variation. However, we do not believe there is much to be gained in attempting to refine the corrosiveness equation further.

We can say with a high degree of assurance that the differences in corrosion rates from mill to mill are definitely related to differences in liquor corrosiveness. Also, that the particular liquor components considered here are important causes of corrosion, although others may also be important. Differences in corrosion experience from mill to mill are not due to chance—they are definitely related to differences in liquor corrosiveness.

PART III—BY C. B. CHRISTIANSEN

From Mr. Lathrop's presentation it is clear that the amounts of sodium thiosulphate, hydroxide, and sulphide present have a very marked influence on corrosion of alkaline pulping digesters.

That as excellent a correlation between liquor corrosiveness and corrosion rate as is given by this hypothesis could be due to chance is highly improbable. In fact, it may be said that the probability of this occurring by chance is less than one in 1000. Further, strong support of the validity of the hypothesis is found in the fact that it not only fits laboratory experimental findings but also the conditions that actually obtain in Canadian mills.

The quantities of sodium hydroxide and sodium sulphide required for cooking are dictated by economics, by the pulp quality desired, and by other operating considerations. They cannot, therefore, be altered freely. The quantity of thiosulphate used, however, is *not* dependent on cooking requirements and every effort should be made to prevent its concentration from increasing. The following methods will avoid undue contact of the liquor with air and hence should reduce the oxidation of the sulphide to thiosulphate:

1. Use steam nozzles as an aid in the shattering of the smelt stream to the dissolvers so as to avoid the necessity for high rates of green liquor recirculation which promote thiosulphate formation in the dissolver.
2. In so far as possible, keep storage tank openings closed to prevent unnecessary air circulation over liquor surfaces.
3. Use instrumentation which does not require the use of air bubble pipes in the green or white liquor systems.
4. Where possible, have discharge openings of transfer lines placed below normal liquor levels. In any event, the transfer lines should be extended far enough into the tanks to avoid impingement or drainage of the liquor on the side of the tank because otherwise this would lead to localized corrosion of the tank.
5. Displace air from the digester before addition of liquor by adding steam through the bottom nozzles during chip filling. (See remarks above under "Secondary Corrosion.")

As was explained by Mr. Lathrop, from the analysis of variation it is seen that almost all of the variation in corrosion rates in Canadian mills is explained by the chemical hypothesis and the secondary corrosion factors described earlier. The contribution of other variables including wood and steel appears to be of less importance.

No significant correlations of wood species with corrosion rates could be found in the case of mills in the Eastern and Great Lakes regions. If variations in corrosion rates actually do occur when different woods from these areas are used, the major influence is probably due to the variations in the liquor strengths and cooking conditions required for the different species.

The use of western species, particularly western red cedar, may give rise to higher rates of attack but no definitive conclusions regarding this could be drawn from the data collected by the task force. In a recent paper MacLean and Gardner (*2*) reported, on the basis of some laboratory work with air-dry sawdust and a liquor composed of only hydroxide and sulphide, that liquor corrosiveness is increased by the use of some western woods in accordance with the following ascending order of influence: western hemlock, Douglas-fir, and western red cedar. (It should be noted that in these experiments the ratio of active alkali to moisture-free wood was much higher than that normally used in mill operations.) Also, in one western mill the corrosion rate in one digester used exclusively for pulping western cedar was 18% higher than the rates in the other three digesters which were used with fir, spruce, and hemlock.

It was not possible to compare the effect of eastern and western woods because complete corrosion data on only two western mills were available for study.

Metallurgical Investigations

It has often been contended that the increase in corrosion in recent years has resulted from changes in steel composition. So as to determine quantitatively the role of steel in digester corrosion, an intensive investigation, comprising 28 separate determinations, was carried out at the Mines Branch, Department of Mines and Technical Surveys, Ottawa on each of 43 steel samples selected by the Institute's metallurgists during the field inspections.

From the analysis of variation it would appear that

only minor variations in corrosion rates among mills can be explained by differences in steel composition. A word of caution, however, is necessary. In the first place, it might be expected that reasons for the variation in rates from digester to digester within a single mill (i.e., approximately 9% of the total variation) and possibly for the dispersion of the mills about the chemical hypothesis regression line may be found in the results of the metallurgical work, the study of which has not been fully completed. There is good evidence from mill experience in the United States that some types of carbon steel (notably high tensile) are less resistant to kraft mill corrosion than are other types. It should be noted that the carbon steels used in all but one Canadian digester now in use are from steel plate of medium tensile strength. The ASTM designations for these steels are A-30, A-70, A-201, and A-285, the specifications of which are quite similar. The major difference among these steels is that killing is mandatory in the case of A-201, whereas deoxidation practice is not specified for the other steels. (Since silicon is used most frequently for killing, the degree of killing practiced by the steel mills has, in the past, determined the silicon content in the resulting plate.) The percentage of residual elements may vary considerably in all of these steels, regardless of specification. Even though the statistical studies of the metallurgical data collected have not been completed, the following *preliminary* observations can be made:

1. One digester fabricated from high tensile strength steel of ASTM specification A-212 showed a higher corrosion rate than the other digesters in the same mill. While this observation is based on only one case, it is in agreement with experience in American mills as reported in a recent TAPPI study, "Comparative Analysis of Digester Corrosion Measurements" by Shoumatoff and Teeple.

2. With the exception of specially formed or cast sections, the steel plates used in a single digester are, in most cases, from the same source. Also, for those digesters from which several steel samples were taken, the variations in steel composition from plate to plate within a digester were found to be slight.

3. The one-piece digester heads which are hot-formed from a single plate appear to be more corrosion-resistant than those formed from several sections of plate.

4. There is some indication that as the amount of silicon in welds increases and the amount of oxygen decreases, corrosion is increased.

5. Although the prevalence of rapid corrosion in the heat-affected zones of the automatic welds indicates that microstructure might be an important factor in corrosion, no evidence to substantiate this possibility could be found in the studies of steel samples from the plates.

6. In two mills welding-neck flanges in digester liquor-circulating lines were unsatisfactory because of early failures of the flanges. In both cases silicon content was found to be higher than that in the iron from the pipe line itself.

Investigation of Equipment Other than Digesters

Concurrent with the study of digester corrosion, all information that could be gleaned from mill files, from maintenance records, from discussions with mill personnel and from careful examinations of other equipment was collected, sorted, and thoroughly analyzed so as to find methods for reducing the serious corrosive attack experienced in this other equipment. Also, attempts were made to correlate the corrosiveness of cooking liquor with chemical factors and operating practices in the liquor recovery cycle.

Although a chemical hypothesis which relates liquor composition to corrosion could not be established for this equipment, a number of factors which influence the corrosive attack in the liquor cycles were uncovered. In addition, several operating practices designed to reduce the formation of thiosulphate in the liquor systems (and hence the corrosiveness of the cooking liquor) were recommended earlier in this paper.

Tables of materials used in the various pieces of equipment and the service life experienced with such materials have been prepared. From those and from the observations of the task force in the mills, recommendations have been made as to materials and operating practices that should be used if satisfactory service is to be obtained. These tables and recommendations will appear in the Institute's final report to the sponsoring companies on the work done. Unfortunately they do not lend themselves to presentation in a paper such as this.

EXPERIMENTAL PROGRAM

Clearly, further pursuit of solutions to this problem will require laboratory experimentation. If one were to start anew without the findings of this project, such an investigation would involve determining the influence of nearly every variable on corrosion over a wide range of values. (Unless one were fortunate enough to select for early study those variables which are most important in regard to corrosion.) Undoubtedly such a study would be exceedingly expensive in terms of time and money, particularly since there is little fundamental knowledge that would be of assistance.

A very marked reduction in the work required has been effected by studying the problem in the mills. No longer is an extensive and time-consuming study indicated into the influence on corrosion of every single element in the steel, of every component of the liquor or of many of the other 125 variables previously suspected of influencing corrosion. Many of these variables are now known to be of minor importance. The proper application of the recommendations of the task force, to paraphrase Sir Winston Churchill, would reduce corrosion in alkaline pulping equipment from an expensive menace to an interesting problem.

LITERATURE CITED

1. Ruus, L., and Stockman, L., *Svensk Paperstidn.* 56, No. 22: 857–865 (Nov. 30, 1953).
2. MacLean, H., and Gardner, J. A. F., *Pulp Paper Mag. Canada* 54, No. 12: 125–130 (Nov., 1953).

Received Nov. 17, 1954. Presented at the 39th Annual Meeting of the Technical Association of the Pulp and Paper Industry, New York, N. Y., Feb. 18–21, 1954.

Although it has been expedient to present this paper under the authorship of C. B. Christiansen and J. B. Lathrop, it is the work of the following which is reported. It should also be noted that several of these persons have assisted in the preparation of this manuscript: Pulp and Paper Research Institute of Canada—C. B. Christiansen, W. A. Mueller, W. C. Grater, and B. W. Burgess; Arthur D. Little, Inc.—J. B. Lathrop, J. T. Hulswit, and A. Thomasian; Metallurgical Consultants to the Pulp and Paper Research Institute of Canada on this Project—H. J. Nichols and S. L. Gertsman.

ASSOCIATION NEWS AND EVENTS

Local Section Meetings

Pacific: March 4, 1955, Everett, Wash., Shibley Award Program. May 18–21, Empress Hotel, Victoria, B. C., joint meeting with Pacific Div., APPA Superintendents Association and Pacific Branch CPPA Technical Section.

Kalamazoo Valley: March 3, 1955, Hotel Harris, Kalamazoo, Mich., Graphic Arts Meeting, Peter Moffett, Kalamazoo Vegetable Parchment Co., chairman. April 7, 1955, Engineering Meeting, D. B. Gearhart, General Electric Co., chairman. May, 5, 1955, Western Michigan College theses presentations—"What Lies Ahead," by Elmer K. Stilbert, Jr., Dow Chemical Co., Midland, Mich. June, 1955, Gull Lake Country Club, annual meeting.

Chicago: March 21, 1955; April 18, 1955; May 16, 1955.

Lake States: March 8, 1955, Elks Club, Kaukauna, Wis., afternoon visit to mill of Thilmany Pulp & Paper Co. April 12, 1955, Conway Hotel, Appleton, Wis., Clarence J. West Memorial Award Program. May 10, 1955, annual meeting.

New England: April 11, 1955, Bond Hotel, Hartford, Conn. June 3–4, 1955, Oceanside House, Magnolia, Mass., annual meeting.

Ohio: March 8, 1955, Manchester Hotel, Middletown, Ohio, "The Use of Optical Instruments," by Richard H. Hunter, April 14, 1955, American Legion Hall, Middletown, Ohio, panel discussion on "The Use of Pigments." May 12, 1955, C. G. & E. Co., Hartwell Clubhouse, Cincinnati, Ohio, annual meeting.

Lake Erie: March 11, 1955, Hotel Carter, Cleveland, Ohio, "Measurement and Control in the Graphic Arts." April 15, 1955, "Recent Developments in Printing Inks." May 13, 1955, annual meeting.

Delaware Valley: March 24, 1955, Engineers Club, Philadelphia, Pa., "Paper Mill Management," by K. O. Elderkin, Bowaters Southern Paper Corp., Calhoun, Tenn. May 26, 1955, Edward J. Albert Award Competition.

Empire State: June 9–11, 1955, Whiteface Inn, Lake Placid, N. Y., annual meeting.

Empire State (Metropolitan District): March 8, 1955, Fraunces Tavern, New York, N. Y., panel discussion on "Printing." April 12, 1955, "Fundamentals of Stock Preparation." May 10, 1955, annual meeting.

Empire State (Northern District): March 10, 1955, Woodruff Hotel, Watertown, N. Y., panel discussion on "Basis Weight and Caliper Control." April 14, 1955, TAPPI Award Paper meeting. Talk by James Sisson. May 11, 1955, annual meeting.

Empire State (Western District): March 8, 1955, joint meeting with CPPA Technical Section, Niagara Branch. April 6, 1955, "Availability of Raw Materials" (Suppliers Night). May 4, 1955, Lockport, N. Y., annual meeting.

Empire State (Eastern District): Feb. 17, 1955; March 17, 1955; April 21, 1955, Glens Falls Country Club, Glens Falls, N. Y., May 21, 1955, annual meeting.

Empire State (Central District): March 4, 1955, University Club, Syracuse, N. Y., "New Developments in Paper Machine Design," by Earl H. Swartz, Beloit Iron Works, Beloit, Wis. April 2, 1955, "Interesting Developments in Titanium Research," by H. C. Brill, Pigments Dept., E. I. du Pont de Nemours & Co., Inc., Newark, Del. May 6, 1955, New York State College of Forestry, Seniors' Night, June 3, 1955, annual meeting.

Maine-New Hampshire: June 24–25, 1955, Eastern Slope Inn, North Conway, N. H., "Paper Machine Operating Problems."

Southeastern: March 18–19, 1955, George Washington Hotel, Jacksonville, Fla. May 13–14, 1955, De Soto Hotel, Savannah, Ga.

Maine-New Hampshire

W. L. Hinds, Keyes Fibre Co., Waterville, Me., has announced details concerning the next meeting of the Maine-New Hampshire Section.

The meeting will be held at the Eastern Slope Inn, North Conway, N. H., on June 24–25, 1955, and will feature "Paper Machine Operating Problems." Individuals or companies desiring to present papers at this meeting are requested to write to Roland Martin, program chairman, Fraser Paper Ltd., Madawaska, Me., prior to March 1, 1955.

Nonfibrous Materials Testing Committee

Keith H. Williams of the Mid-States Gummed Paper Co., Chicago, Ill., has been appointed chairman of the TAPPI Nonfibrous Materials Testing Committee, succeeding James R. Lyon of Atlas Boxmakers, Inc., Chicago, Ill.

There are three active projects being worked upon by the committee: clays, glue, and opaque pigments.

The chairman would appreciate suggestions from members of the Technical Association for new nonfibrous materials testing projects which should receive the attention of the committee.

Requests for Information

Items published in advertisements, *Tappi* Industry Notes, and elsewhere in this magazine result in inquiries being sent to the companies referred to by readers of *Tappi*.

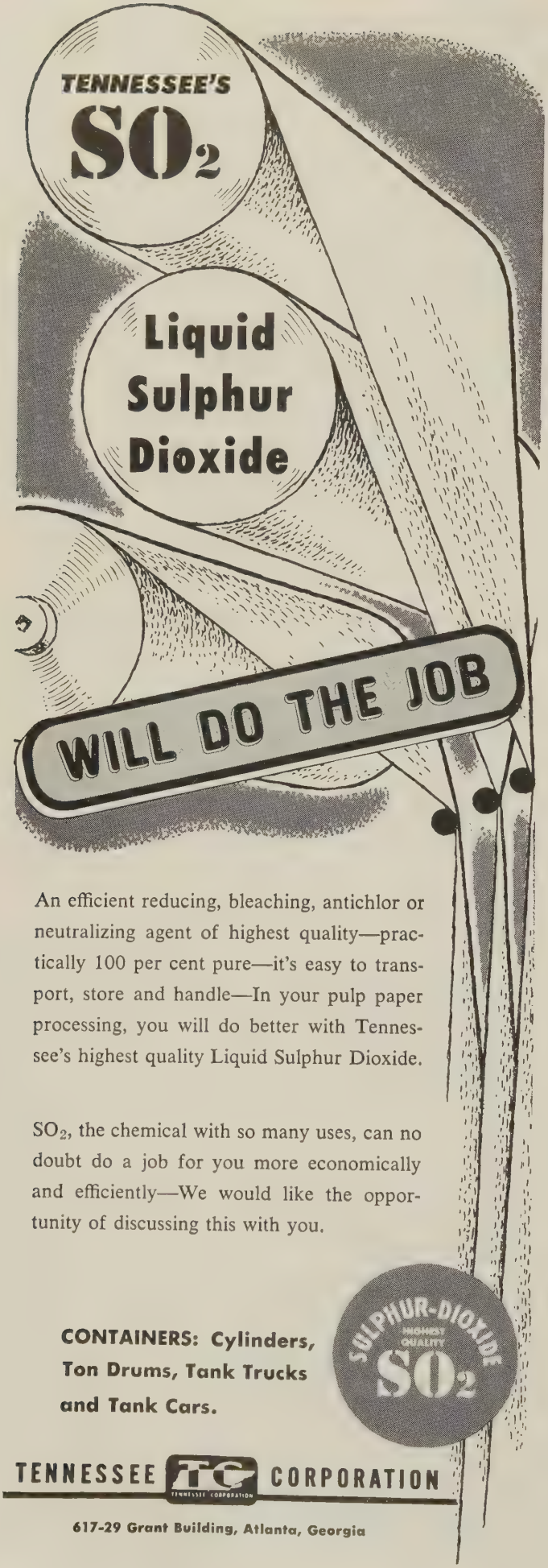
In many cases the company is aware of the source of the inquiry but not always are these sources mentioned by the inquirers. The same omission is made in regard to all of the publications serving the industry.

Some advertisers use, as a yardstick of reader interest, the number of inquiries they receive from business advertising and publicity.

New TAPPI Corporate Members

The following companies became corporate members of the Technical Association in 1954:

Associacion Fabricantes de Paper, Buenos Aires, Argentina
Bengal Paper Mill Co. Ltd., P. O. Raniganj, W. Bengal, India
Bowaters Southern Paper Corp., Calhoun, Tenn.
Buntpapierfabrik A/G, Aschaffenburg, Germany
Cartiera Italiana S.p.A., Turin, Italy
Cartonneries Mecaniques du Nord, Gravelines (Nord), France
Celulosa de Chihuahua, S. A., Chihuahua, Chih., Mexico
Florida Palms, Inc., Okeechobee, Fla.
Gadelius & Co., Ltd., Tokyo, Japan
Grycksbo Pappersbruk AB, Grycksbo, Sweden
Industrijaki Biro, Ljubljana, Yugoslavia
Inex, S. A., Barcelona, Spain
E. & M. Lamort Fils, Vitry-le-Francois (Marne), France
L'Ondulium Vitry-sur-Seine, France
Marusho Industrial Co., Ltd., Kobe, Japan
Masonite (Africa) Ltd., Estcourt, Natal, S. A.
Orient Paper Mills Ltd., Brajrajnagar, India



An efficient reducing, bleaching, antichlor or neutralizing agent of highest quality—practically 100 per cent pure—it's easy to transport, store and handle—In your pulp paper processing, you will do better with Tennessee's highest quality Liquid Sulphur Dioxide.

SO_2, the chemical with so many uses, can no doubt do a job for you more economically and efficiently—We would like the opportunity of discussing this with you.

CONTAINERS: Cylinders, Ton Drums, Tank Trucks and Tank Cars.

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South African Pulp & Paper Industries Ltd., Zululand, Natal, S. A.
Stanford Research Institute, Stanford, Calif.
Tielens Freres & Cie, Meerssen, Holland
Titaghur Paper Mills Co. Ltd., Calcutta, India
Tribeni Tissues Ltd., Tribeni, Bengal, India

New TAPPI Sustaining Members

The following companies became sustaining members of the Technical Association in 1954:

Airkem, Inc., New York, N. Y.
Bensing Bros. & Deeney, Philadelphia, Pa.
Bowser, Inc., Fort Wayne, Ind.
Brandon Sales, Inc., Greenville, S. C.
Brooks Rotameter Co., Lansdale, Pa.
Chemipulp Process, Inc., Watertown, N. Y.
Chicago Bridge & Iron Co., Birmingham, Ala.
Cities Service Oil Co., New York, N. Y.
Cleaver-Brooks Co., Milwaukee, Wis.
Croll-Reynolds Co., Inc., New York, N. Y.
DeZurik Shower Co., Sartell, Minn.
Dowell, Inc., New York, N. Y.
Electric Steel Foundry Co., Portland, Ore.
Elliott Company, Pittsburgh, Pa.
Fawick Airflex Div., Cleveland, Ohio
Felker Bros. Mfg. Co., Marshfield, Wis.
Goodyear Tire & Rubber Co., Akron, Ohio
Gould Pumps, Inc., Seneca Falls, N. Y.
Huntington Rubber Mills, Inc., Seattle, Wash.
Mount Hope Machinery Co., Taunton, Mass.
Oldbury Electro-Chemical Co., New York, N. Y.
Parsons & Whittemore, Inc., New York, N. Y.
Patton Mfg. Co., Inc., Springfield, Ohio
Polymer Corp., Ltd., Sarnia, Ont., Canada
Reynolds, Smith & Hills, Jacksonville, Fla.
Rhodia, Inc., New York, N. Y.
Seelye Stevenson Value & Knecht, New York, N. Y.
Sheffield Corp., The, Dayton, Ohio
Simonds Saw & Steel Corp., Fitchburg, Mass.
Smith & Co., F. L., New York, N. Y.
Taber Instrument Corp., North Tonawanda, N. Y.
Union Starch & Refining Co., Columbus, Ind.
Waterbury & Sons Co., H., Oriskany, N. Y.
Wiegand Co., Edwin L., Pittsburgh, Pa.

Mechanical Pulping Conference

A meeting was held at the Hotel Putnam, Bennington, Vt., on Jan. 14, 1955, for the purpose of discussing plans for the second International Mechanical Pulping Conference. Those present were: Thomas F. LaHaise, Jr., Imperial Paper & Color Corp., Plattsburg, N. Y., general chairman for the conference; John H. White, Keyes Fibre Co., Waterville, Me., program chairman; and Jack Winchester, TAPPI, New York, N. Y.

A questionnaire had been sent to all groundwood mills in the U. S. and Canada to determine what type of program would be most popular. An analysis of the returns indicated that most people favored panel discussions during which comparisons would be made among the several geographical areas of the continent where groundwood is produced, for the purpose of bringing out differences in the operating practices used to make various grades of groundwood. It had been decided to make such group discussions a feature of the conference. However, the committee felt that ample attention should also be given to recent innovations in the mechanical pulping field, such as the Norton experimental stone, pitless grinding, and chemigroundwood.

The theme of the conference, "Groundwood—Its Increasing Potential," will keynote both the panel discussions and the formal technical sessions. The conference is to be held at Poland Spring House, Poland Spring, Me., Sept. 19–22, 1955.

Mr. LaHaise is general chairman for the meeting, and is being assisted by a program committee consisting of Mr. White, W. H. de Montmorency, Pulp and Paper Research Institute of Canada, Montreal, Quebec, and F. Fulton, Consolidated Paper Co., Shawinigan Falls, Quebec.

LETTERS TO THE EDITOR

Rubber Covered Top Press Rolls

To the Editor, *Tappi:*

Can you give us any information on the use of rubber covered top press rolls working in conjunction with rubber covered suction rolls on high-speed newsprint machines?

We understand some particular form of doctor is required and that the rubber may be of a special composition and hardness. It has been said that such an arrangement is in operation at Port Angeles, Wash., and that they have had a good experience there with increased life of wet felts. We are, however, not so much interested in increased felt life, as in reduced moisture content of paper entering the drier part. Every 1% reduction here is of great interest to us as we are speeding up a newsprint machine with insufficient number of driers for the speed at which we are running.

Would you be good enough to get some information for us, particularly on the question of removal of moisture? The argument in favor, we understand, is a rubber top roll on rubber covered shell has a much broader nip contact and that this removes more water.

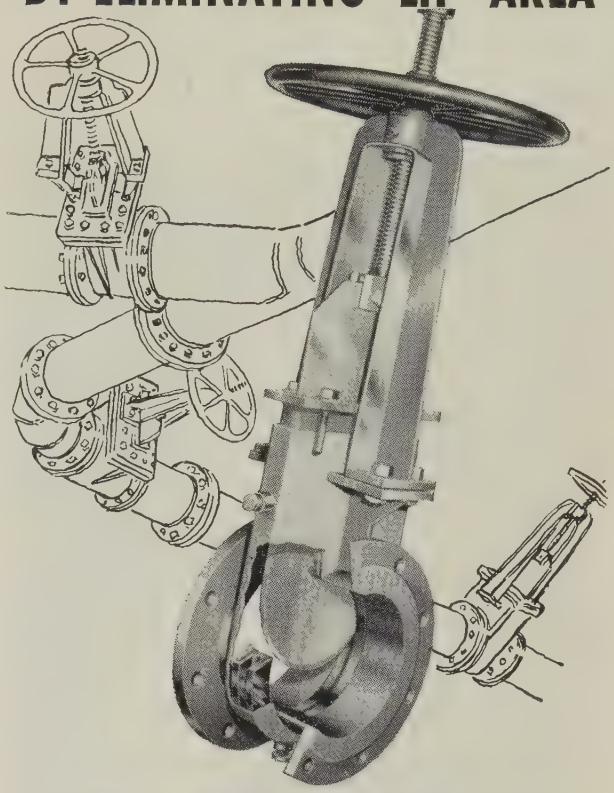
W. G. Moore
Clyde Paper Co., Ltd.
Rutherglen, Scotland

To the Editor, *Tappi:*

We believe you have reference to our Self-Skinner composition which is used in some mills on newsprint machines. In fact, we do have one or two of these rolls operating at Crown Zellerbach Corp., Port Angeles, Wash.

This Self-Skinner composition, when used as a top press roll on newsprint machine usually has a hardness of plasto 45. You will undoubtedly recognize that this is considerably softer than what we shall call the conventional top press such as Rub Roc, Stonite, Grand Elastic, or Granite. Regarding moisture removal when operating with this softer roll, the writer can only say that from reports received from the field they are obtaining in most cases, slightly more moisture removal at the first press with the softer roll due to the fact that a more generous nip is obtained over the suction box and, therefore, more water is extracted via this method. In addition to this, the felt is, of course, increased considerably. In some instances, our Self-Skinner roll is operating without the use of a doctor, however, it can be doctored successfully by using either a Micarta or hard rubber doctor blade. It must be remembered however, that if a roll of this hardness is doctored, a spray of water must be kept on the doctor blade to make certain that the blade does not score the surface of the roll. This is usually accomplished by running a dam of water over the doctor blade and controlling the amount of water on the roll by connecting a hose to your suction line on ether end of the roll. Generally speaking, we would suggest using a Micarta blade, 1/8 in. thick, placed against the roll in its rectangular shape with no bevelling whatsoever and permitting the blade to wear its own edge. When the blade becomes worn to the point where water is seeping under it and following the roll, the blade should be cut back to a slight bevel and returned to service.

PREVENT STOCK BUILD-UP
BY ELIMINATING "LIP" AREA



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"RUBBER SEATING"
FABRI-VALVE

New "Rubber Seating" Fabri-Valves completely eliminate "lip" area leaving nothing for stock to "hang up" on. Rubber seats press tightly together when gate is open (see illustration) insuring free flow of heavy solution from port to port. Rubber seats prevent wear and galling on gate, insure tight shut-off for normal flow or back pressure, and can be easily and economically replaced. New "Rubber Seating" Fabri-Valves offer low-cost original installation and reduced maintenance. They cost less...are cheaper to ship and install. Custom fabricated in 4" to 24" size from stainless steel, monel, nickel or any alloy combination.

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COMPANY OF AMERICA
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SOUTHERN CORPORATION — Charleston, S. C., Distributor for Eastern and Southern area
FELKER BROS. • • • • — Marshfield, Wis., Distributor for the Mid-Western area

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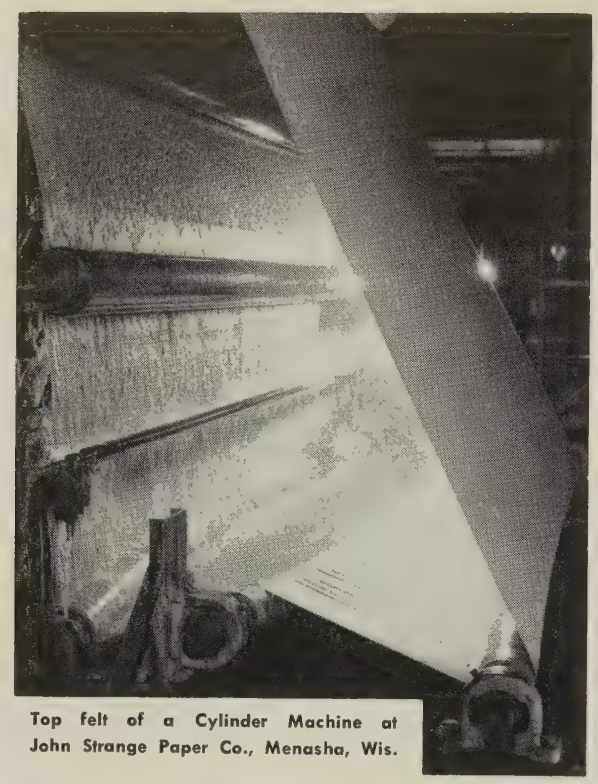
PROLONG EFFICIENT LIFE

of

CYLINDER MACHINE FELTS



Top felt of a Cylinder Machine at John Strange Paper Co., Menasha, Wis.

Mount Hope

FELT PRESERVER UNIT

Keeps Felts Soft, Open, "Alive"

Our revolutionary new unit keeps cylinder machine felts open-pored and soft, at peak efficiency almost for life. Allows use of heavy weight sheet during entire felt life—saves waste of time and stock when you want to change paper weight. Helps keep felt aligned, straightens seam, reduces tension on felt and slices—actually allows use of narrow felt. Eliminates whippers, to save felt wear. Saves time in washing, even saves water!

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In order to comment further, relative to moisture removal when operating with a softer top press roll, the writter recalls one mill which is running a bond with a top Self-Skinner press roll in the first press position having a plasto test of 95 and they are obtaining slightly more moisture removal than they obtained previously with a Granite roll.

James E. Post, *Special Representative*
Manhattan Rubber Division
Raybestos-Manhattan, Inc.
Passaic, N. J.

Pigment Binding Ability

To the Editor, *Tappi:*

We are in search of a testing method for the determination of the pigment binding ability of binding agents and herewith ask to inform us whether such a process is known to you.

When manufacturing coated papers, the materials used as binding agents, such as casein, size or dispersions of plastics, dependent on their provenance and composition, show great differences in their ability to bind pigments, e.g., blanc fixe, china clay, or satin white.

In the laboratories of the German paper coating firms, the binding ability is usually tested by means of the so-called "fingerprint test" at which a slightly wetted finger is firmly pressed on the paper for one second and then removed with a jerk. Naturally, this procedure requires great experience and works only out at subjective values and therefore does not allow a numerical valuation. Up to which extent the known Dennison test can be applied, we cannot judge, lacking any experience.

The required testing method should even permit the determination of small differences of the pigment binding ability of a binding agent which is not possible with the fingerprint test. The ascertainment of small differences in the pigment binding ability is, e.g., necessary if one drives at a reduction of the binding agent by adding certain admixtures to the coating dyes.

Buntpapierfabrik A. G.
Aschaffenburg, Germany

To the Editor, *Tappi:*

The problem of determining the binding power of adhesives, both in respect to pigments as well as to the base stock, has not been resolved to the extent that a standard method has been adopted universally.

I believe that the method which you mention, that of applying a moistened finger to the sheet, has been and is being used as a rough control. However, it has the disadvantage that it is subject to personal evaluation, so to overcome this the Dennison waxes were developed. These waxes are numbered according to their melting points and relative adhesiveness and have been widely adopted. The method of test is given in TAPPI Standard T 459 "Wax Test for Surface Strength of Paper." This test, too, has its limitations. The results do not always conform to the performance of the sheet on the press and the introduction of the high polymer adhesives, such as synthetic latex, introduced the factor of mutual compatibility of adhesive and wax. The two tend to blend chemically to give results that do not conform to performance.

This has brought about the development and introduction of a number of print testers which are supposed to simulate press conditions. These have ranged from proof presses to special devices to create varying degrees of tack between ink and the paper. To date, I have seen no objective comparison so that it is impossible to offer any recommendation. There are many references in the literature to support the varied methods that have been advanced.

The following procedure is more or less general. A plant selects a standard product, usually based on its acceptable commercial performance. This is used in definite amounts

with a definite amount of pigment or on a direct basis with another adhesive or shipment in proportions according to its mill practice. The comparison is done in a stepwise fashion, say in increments of 5% based on the weight of pigment. If the adhesive is known to be noncompatible with Dennison waxes, these are used. However, if the waxes and the adhesive are compatible, it is necessary to use a proof press or similar device. In some plants this is carried further by rechecking the finished product and making a comparison with the laboratory results. Regardless of the method used, it is customary, in their finished product, to exceed the laboratory specification, the degree dependent on the mill's confidence in its control.

Groups within this Association are very interested in this problem and their activities, as well as papers on the subject, are published in the Association's magazine, *Tappi.*

R. T. Bingham, *Asst. Editor*
Tappi, New York, N. Y.

Urea-Formaldehyde in Wood Flour

To the Editor, *Tappi:*

A local wood flour company has submitted to us samples of their product on which they wish to have the percentage, if any, of urea-formaldehyde determined.

So far, we have been unable to find any procedure for testing and analyzing this material in wood flour.

We are wondering if you could help us by citing where we might find such a procedure in any of your previous or current publications.

M. S. Maddess
Bennetts Chemical Laboratory, Inc.
Tacoma, Wash.

To the Editor, *Tappi:*

After considering the letter from Bennetts Chemical Laboratory, Inc., I would offer the following:

1. Upon checking with our technical personnel, I find that we have no specific quantitative method for the determination of urea-formaldehyde in wood flour.

2. If the urea-formaldehyde is present in the wood in an uncured state it can be solvent extracted (perhaps with water) and the amount present determined either through nitrogen analysis or determination of formaldehyde following acid hydrolysis.

3. If the urea-formaldehyde resin is present in a cured state, the amount could be determined by nitrogen analysis such as the Kjeldahl method. In so doing, however, it would be well to run a nitrogen blank on wood flour, known to be free of the resin, since a small quantity of nitrogen is present in the wood alone. The amount of nitrogen determined in the blank would, of course, be subtracted from that in the resin-containing wood as a correction. If the actual urea-formaldehyde resin composition is unknown the results probably will not be too far off if calculated on the assumption that it is dimethylol urea.

J. C. Pullman, *Manager, Technical Service*
American Cyanamid Co. New York, N. Y.

Semichemical Pulping

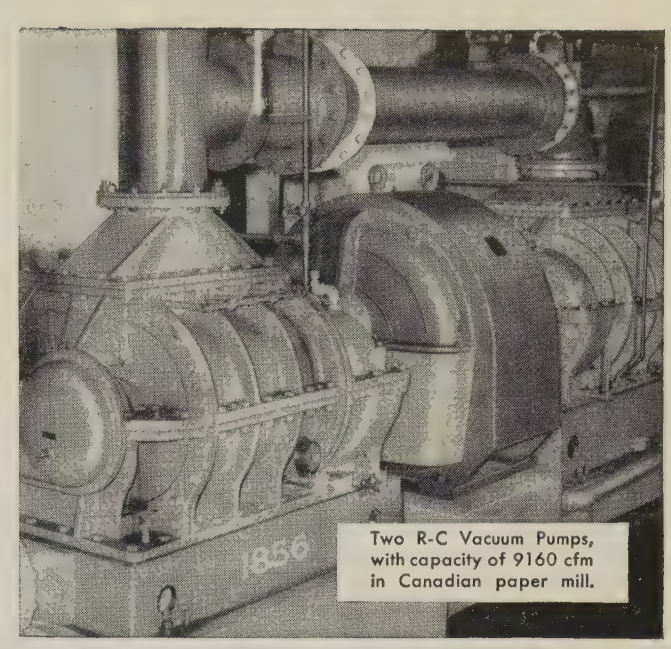
To the Editor, *Tappi:*

1. When neutral sulphite semichemical pulp is cooked in an acid sulphite digester will (a) the bricks, (b) the cement, hold up?

2. What is the best lining, (a) brick, (b) cement, for a digester used with neutral sulphite semichemical pulping?

3. Will the high-cooking pressure, 100 to 110 lb., cause problems in connection with the use of a lining?

J. N. McGovern, *Chairman*
TAPPI Semichemical Pulping Committee



Two R-C Vacuum Pumps, with capacity of 9160 cfm in Canadian paper mill.

Only R-C Vacuum Pumps give you these "BIG 4" Values

More and more paper mills are collecting continuing dividends from this exclusive combination of Roots-Connersville advantages:

1 Reduced horsepower at higher speed
—power savings up to 25% and substantial reduction in first cost of motors result from operation at 600 rpm and up.

2 Long-time reliability and low maintenance
—simple design, without internal contacts or excessive wear, brings almost complete freedom from down time and lost production.

3 Small floor space—less expensive foundations
—because of large capacity per unit and direct connection to high-speed motors. Narrow widths especially adaptable to crowded space.

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To lower first cost and increase operating efficiency, call in the R-C engineer to survey your present pumps and help select new equipment. For basic information, write for Bulletin 50-B-13.

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A DIVISION OF DRESSER INDUSTRIES, INC.
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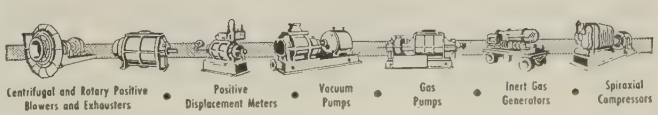
Centrifugal and Rotary Positive Blowers and Exhausters • Positive Displacement Meters • Vacuum Pumps • Gas Pumps • Inert Gas Generators • Spiroxial Compressors

To the Editor, *Tappi:*

We note that you raise several questions regarding the performance of the brick and the joint materials and we will be pleased to answer your questions to the best of our ability.

With regard to the brick materials themselves we have used our CHEM-D digester brick which is the face quality brick used in an acid sulphite digester. This has held up very well in service and we have no reason to believe that we would have to go to a different type of brick such as carbon. The ceramic brick should withstand the conditions inasmuch as they are designed to take a highly acid solution and, although they would not hold up well under strong alkaline conditions, such would never be expected to occur in a neutral sulphite digester. Even with the large amount of buffer, perhaps 20% or so on the total chemical present at the beginning of the cook, the alkalinity is not of a sufficient magnitude to cause any difficulty with the presently used ceramic brick. With regard to the joint material a high proportion of the sulphite digesters, that is acid sulphite digesters, in operation today, utilize a furfural resin cement for the joint material. In an existing lining this would be expected to hold up very well under neutral sulphite conditions inasmuch as our own Chemfural cement, for example, will withstand a pH ranging all the way from extremely acid to about 11.0 on the alkaline side and up as high as 350–360°F. without signs of deterioration. As far as the old litharge joint is concerned, this would be expected to give service for a considerable length of time. Neither of these joints are indicated for continued use in new linings inasmuch as they are excessively expensive for the requirements.

We have been using, with great success, a portland cement joint employing silicate of soda and we have had very good results from this joint material. The high-cooking pressures, namely 100 p.s.i. or over, have not, as yet, caused us any problems whatsoever. At least one mill in Wisconsin is cooking at 100 p.s.i.g. with one of our semichemical linings and plans to reline a second one in the near future for operation at 110 p.s.i.g.

These linings are normally a single laid lining accommodating one course of brick with the portland cement—silicate of soda joint material with a poured cement grout backing. Thicknesses would be expected to average 5 to 6 in. although this would vary with the particular digester used. One digester lining which we have in Wisconsin is a sulphite digester and the lining was made thick enough to get over the inside straps but we would say offhand that 5 in. would probably be minimum thickness which we would like to use in a welded shell where there are no inside straps to contend with. The experience on carbon brick digester linings for kraft mill use has indicated that the 5-in. thickness is about the least that is likely to be very secure and long lived.

Actually the problem is quite simple and we feel that our CHEM-D digester brick with the portland cement—silicate of soda joint and the cement grout backing is as good a lining as can be utilized for the average neutral sulphite service. In addition to this they are somewhat cheaper than the average sulphite digester and as a result do not represent excessive capital cost to a mill.

T. E. Detcher, *Vice-President*
Chemical Linings, Inc.
Watertown, N. Y.

Corrosion of Evaporator Tubes

To the Editor, *Tappi:*

Ed. Note: The following letter is a response to a letter from F. A. Renwick, Tribeni Tissues, Ltd., Calcutta, India, which appeared in this section of the January issue of *Tappi.*

MODEL
AK
FOR ACCURACY — FINEST FINISHES
HANCHETT
knife grinders
for the
PULP AND PAPER
INDUSTRIES
SPEEDS — 10′ to 100′
30′ to 150′ and faster.
MOTORS — 7½hp. to 40 hp.
WEIGHTS — 10 tons up to 40 tons.
CAPACITY — 84″ to 360″ and longer.
Mechanical or hydraulic head carriage drive
for flat or concave bevel grinding.
FOR GRINDING — HOG — BARKER
PAPER TRIMMER AND DOCTOR BLADES
NEW
MODEL
SK-24
slitter knife grinder
FOR TOP — BOTTOM SLITTERS
CAPACITY 3″ TO 24″ DIAMETER
SEMI OR FULL AUTOMATIC
FINEST IN ACCURACY AND FINISH
Other Models.
GK — medium heavy duty — capacity 32″ to 184″
DN — normal production — capacity 32″ to 108″
HANCHETT MANUFACTURING COMPANY
World's Largest Manufacturer of Knife Grinding and Saw Sharpening Machinery
MAIN OFFICE — Big Rapids, Michigan
WEST COAST — Portland, Oregon

In the following paragraphs I shall answer Mr. Renwick's four questions in chronological order, passing on such information as has come to our attention in dealing with various sulphate kraft mills in this country.

1. We can say that there is a definite trend toward the use of stainless steel tubes in all evaporator bodies in kraft mills. While the evaporator is usually purchased from the fabricator with stainless steel tubes in only the first, or sometimes the first and second, effects, the customer frequently replaces the other effect tubes with stainless steel on the first retubing as the tax picture is more favorable to him when these stainless steel tubes are purchased on M & O.

2. Little trouble is encountered on the vapor, or shell side after stainless steel tubes are installed but, when carbon steel tubes are being used, it has been found that one of the amines on sale by various companies can be employed with excellent results.

One such company in the United States is the Hagan Corp. who manufacture a product with the trade name of "Hagafilm." I know of one black liquor evaporator in which this substance is introduced at the rate of about 10 p.p.m. into the vapor pipe, ahead of each effect with carbon steel tubes. The customer finds that this not only removes scale already formed but prevents the formation of further scale and greatly improves heat transfer. (Please note: we have no connection in any way with any company manufacturing or distributing this product.)

3. I have always assumed that most of the scaling on the shell side was due to the presence of H_2S and mercaptans in the vapor but I do not know of any low alloy, low cost steel which is satisfactory. Some of the western mills have advocated the use of the 400 series stainless steels but I do not agree that they would be satisfactory, especially when cooking soft woods.

4. It is customary to use 2 in. $\times$ 16 gage type 304 stainless steel tubes in long tube evaporators running on black liquor.

James Mair, *Vice-President*
Goslin-Birmingham Mfg. Co., Inc.,
Birmingham, Ala.

Glossmeters

To the Editor, *Tappi:*

We are in the process of modifying three Bausch and Lomb 75° glossmeters for a paper mill to make them read alike and in conformity with TAPPI Method T 480 m-51.

We make three changes in each instrument:

1. Install a $^3/_4$-in. receptor window and lens at the front end of the receptor tube to comply with the geometric requirements of TAPPI Standard T 480 m-51,

2. Put a short-focus projecting lens in the source beam to focus on this new receptor window,

3. Remove adjusting potentiometers to reduce resistance in the photocell circuit and install an adjusting solenoid which permits standardization by adjustment of lamp intensity, yet has no sliding contact to give instability.

Since your readers have from time to time written of their problems in standardizing the Bausch & Lomb glossmeter, we think they may be interested to know of these alterations we have designed.

Richard S. Hunter
Hunter Associates Laboratory,
Falls Church, Va.

Alamask *The original masking agent for kraft mill odor abatement.*

Abatement *Improved product design makes possible malodor abatement in gaseous and liquid effluents from sulphate operations.*

Assistance *"Alamask"® and Rhodia's experienced engineering section can assist the kraft pulp industry in its study and efforts to abate malodorous sulfur compounds.*

Available *From Rhodia, Inc., New York, successor to E. I. duPont de Nemours & Co., Alamask reodorants.*

Based on your answers to 26 simple questions, our technical staff can tell you how Alamask will help you negate your mill malodors. Send for the questionnaire today.

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Please send the "Alamask Odor Abatement Questionnaire" to:

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COMPANY_____

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PERSONAL MENTION

Items About New and Old Tappimen

New TAPPI Members

George L. Adamson, President, Adamson University; Adamson University Testing Laboratories, Manila, Philippines, a 1924 graduate of National and Technical Universities of Athens, with a Ph.D. degree in 1927.

Sigvald Andersen, Electrical Engineer, West Virginia Pulp & Paper Co., New York, N. Y., a 1941 graduate of Polytechnic Institute of Brooklyn.

William C. Andrews, Chemist, West Virginia Pulp & Paper Co., Mechanicville, N. Y., a 1950 graduate of Siena College.

Kenneth Arnold, Manager, Paper Dept., Stein, Hall & Co., Inc., New York, N. Y. Attended Columbia College.

John B. Banton, Chemist, S. D. Warren Co., Copsecook Mill, Gardiner, Me., a 1951 graduate of the University of Maine.

Gerald J. Bayern, Assistant Director, Foster D. Snell, Inc., New York, N. Y., a 1947 graduate of Columbia University.

Ralph L. Beach, Jr., Director of Package Research, International Paper Co., Container Div., Whippany, N. J. Attended Rutgers University.

William H. Bechtel, Quality Control Supervisor, National Gypsum Co., Mobile, Ala., a 1936 graduate of the University of Dubuque.

Henry W. Bollinger, Techical Director, Smeallie & Voorhees, Inc., Amsterdam, N. Y.

Richard C. Breiner, Research Chemist, Johns-Manville Corp., Manville, N. J., a 1949 graduate of Brooklyn College.

George C. Brown, Assistant to Manager, Paper Div., Price Brothers & Co. Ltd., Quebec, P. Q., Canada, a 1940 graduate of McGill University.

Fred L. Buchanan, Plant Manager, National Gypsum Co., Pryor, Okla. Attended Tri-State College.

Paul A. Chapman, Manufacturers' Representative, Johnson City, Tenn. Attended Georgia Institute of Technology.

Stuart R. Cooper, Junior Chemical Engineer, Oxford Paper Co., Rumford, Me., a 1953 graduate of the University of Maine.

Robert E. Crossley, Electrical Engineer, Great Northern Paper Co., Millinocket, Me., a 1950 graduate of Rensselaer Polytechnic Institute.

George Dlesk, Operations Manager, American Box Board Co., Filer City, Mich., a 1939 graduate of the University of Illinois.

Rene Dosne, Director, Technical Service, Riordon Sales Corp. Ltd., New York, N. Y., a 1914 graduate of the University of Paris.

Donald F. Durso, Organic Group Leader, Buckeye Cotton Oil Co., Memphis, Tenn., a 1951 graduate of Purdue University with a Ph.D. degree.

Charles C. Edson, Vice-President in Charge of Manufacturing, Kable Printing Co., Mount Morris, Ill. Attended Ohio State University.

Russell K. Elston, Research Chemist, Potlatch Forest, Inc., Lewiston, Idaho, a 1947 graduate of the University of Wisconsin.

Wilhelm B. Engelstad, Chief Engineer, A/S Hunton Bruk, Gjovik, Norway, a 1924 graduate of Norway Technical Institute.

Herbert F. Fishburn, Sales Engineer, Williams-Gray Co., Chicago, Ill., a 1940 graduate of Purdue University.

David W. Flotow, Technical Service Engineer, Hercules Powder Co., Kalamazoo, Mich., a 1950 graduate of Michigan College of Mining and Technology.

Per E. Fodnaess, Student, University of Maine, a 1950 graduate of the National Technical Institute, Goteborg, Sweden.

Richard R. Fox, Assistant Pulp Mill Superintendent, St. Lawrence Corp. Ltd., Montreal, P. Q., Canada.

William R. Gardiner, Director-Treasurer, The Paper Bag Institute, Inc., New York, N. Y.

Francis E. Getchell, President, Florida Palms, Inc., Okeechobee, Fla.

Brage Golding, Chemical Engineer, Lilly Varnish Co., Indianapolis, Ind., a 1948 graduate of Purdue University with a Ph.D. degree.

Barrett K. Green, Head, Fundamental Research Dept., The National Cash Register Co., Dayton, Ohio, a 1928 graduate of Cornell University.

W. Andrew Green, Jr., Chief Engineer, Manchester Board & Paper Co., Inc., Richmond, Va., a 1941 graduate of the University of Virginia.

Edgar B. Gutoff, Manager, Process Design Div., Brown Co., Berlin, N. H., a 1954 graduate of Massachusetts Institute of Technology with an Sc.D. degree.

Elden D. Haller, Research, Arthur H. Thomas Co., Philadelphia, Pa., a 1933 graduate of Ohio State University with a Ph.D. degree in 1940.

Percy A. Harding, Assistant Night Superintendent, International Paper Co., Chisholm, Me., a 1947 graduate of Colby College.

Walter Harz, Director, Phrix-Werke A/S, Hamburg, Germany, a 1924 graduate of Hamburg University with a Ph.D. degree.

Eugene C. Hilkert, Chemical Sales Development, Koppers Co., Inc., Pittsburgh, Pa., a 1942 graduate of the University of Notre Dame.

Kaz Horita, General Mill Superintendent, Container Corp. of America, Chicago, Ill., a 1945 graduate of Illinois Institute of Technology.

Paul Kaplan, Manager, Technical Div., Stein, Hall & Co., New York, N. Y., a 1944 graduate of Rose Polytechnic Institute.

Clair L. Keene, Vice-President, Mutual Boiler & Machinery Insurance Co., Boston, Mass., a 1944 graduate of the Illinois Institute of Technology.

Richard F. Kelley, Development Engineer, The Mead Corp., Chillicothe, Ohio, a 1950 graduate of the Ohio State University.

Frank A. Kruglinski, Sales Manager, General Corrugated Machinery Co., Palisades Park, N. J.

Leonard B. Lane, Manager, Technical Service Dept., Armour & Co., Adhesives Div., Chicago, Ill., a 1921 graduate of Purdue University.

John H. Langstaff, Technical Sales Representative, Monsanto (Canada) Ltd., Ville LaSalle, P. Q., Canada, a 1949 graduate of McGill University.

William P. C. LeBoutillier, Mill Manager, Price Brothers & Co. Ltd., Riverbend, P. Q., Canada, a 1927 graduate of McGill University.

George C. Lecky, Quality Control Director, F. J. Kress Box Co., Pittsburgh, Pa., a 1931 graduate of Carnegie Institute of Technology.

John A. Manning, Research Chemist, General Electric Co., Pittsfield, Mass., a 1937 graduate of Columbia University.

Robert H. Marchessault, Research Chemist, American Viscose Corp., Marcus Hook, Pa., a 1954 graduate of McGill University with a Ph.D. degree.

Georges P. Martin, Engineer, Papeteries Bollore, Paris, France.

James W. McSwiney, Executive Assistant to the President, The Mead Corp., Dayton, Ohio. Attended Furman College, University of Tennessee and Harvard University.

William C. Miller, Chemist, The Sorg Paper Co., Middletown, Ohio, a 1938 graduate of Mercer University.

Jacob B. Morrison, Corrosion Engineer, Crucible Steel Co. of America, Midland, Pa., a 1939 graduate of Pennsylvania State University.

Remmelt Nijhuis, Technical Representative, Patexol Products, Inc., Syracuse, Ind. Attended the Textile College, Enschade, Holland.

Sidney Nuss, Assistant Mill Manager, A.P.W. Products Co., Inc., Albany, N. Y.

Russell C. O'Gee, Director of Research, O-Cel-O Div., General Mills, Inc., Buffalo, N. Y., a 1951 graduate of the University of Buffalo with a Ph.D. degree.

Guiseppe Panza, Partner, Milano, Italy.

Paul J. Pernice, Technical Representative, General Dyestuff Co., Portland, Ore., a 1947 graduate of Fordham University.

Theodore H. Perry, Mill Manager, Kimberly-Clark Corp., Neenah, Wis., a 1931 graduate of the University of Wisconsin.

Demeter Prelovsek, Project Engineer, Industrijski Biro, Ljubljana, Yugoslavia, a 1936 graduate of the Technical University at Darmstadt, Germany.

Donald Read, Chief Chemist, Sands & McDougall Pty. Ltd., Melbourne, Victoria, Australia, a graduate of the Royal Melbourne Technical College.

John D. Reagh, Jr., Associate Director of Research, Weyerhaeuser Timber Co., Everett, Wash., a 1940 graduate of Cambridge University, England, with a Ph.D. degree.

E. Hays Reynolds, Assistant Sales Manager, Keever Starch Co., Greenville, S. C., a 1947 graduate of Clemson College.

Arthur L. Rothschild, Chief Chemist, Standard Paper Mfg. Co., Richmond, Va. Attended the University of Richmond.

Bernard W. Rudiger, Supervisor of Power, West Virginia Pulp & Paper Co., New York, N. Y., a 1937 graduate of Stevens Institute of Technology.

Willie St. Laurent, Consulting Engineer, Montreal, P. Q., Canada.

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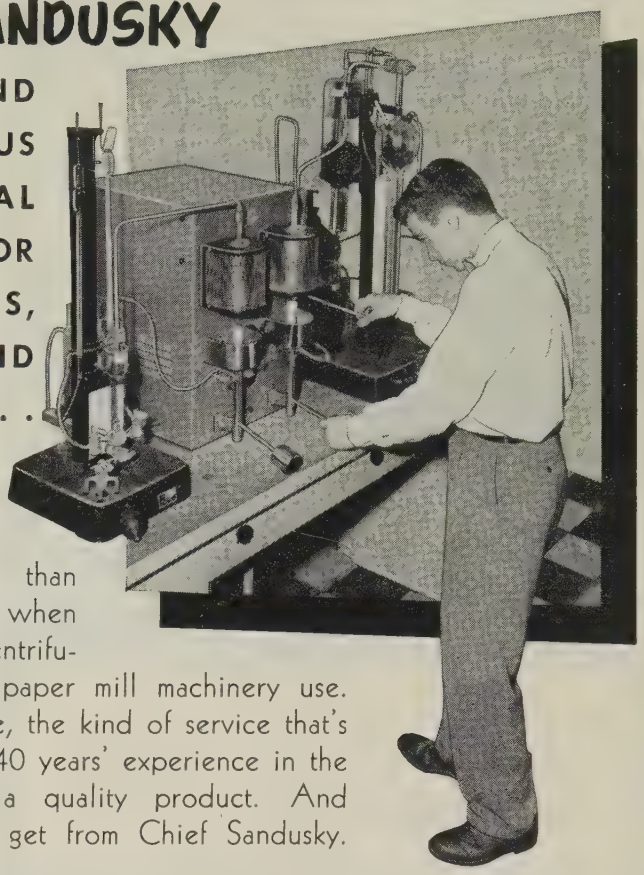

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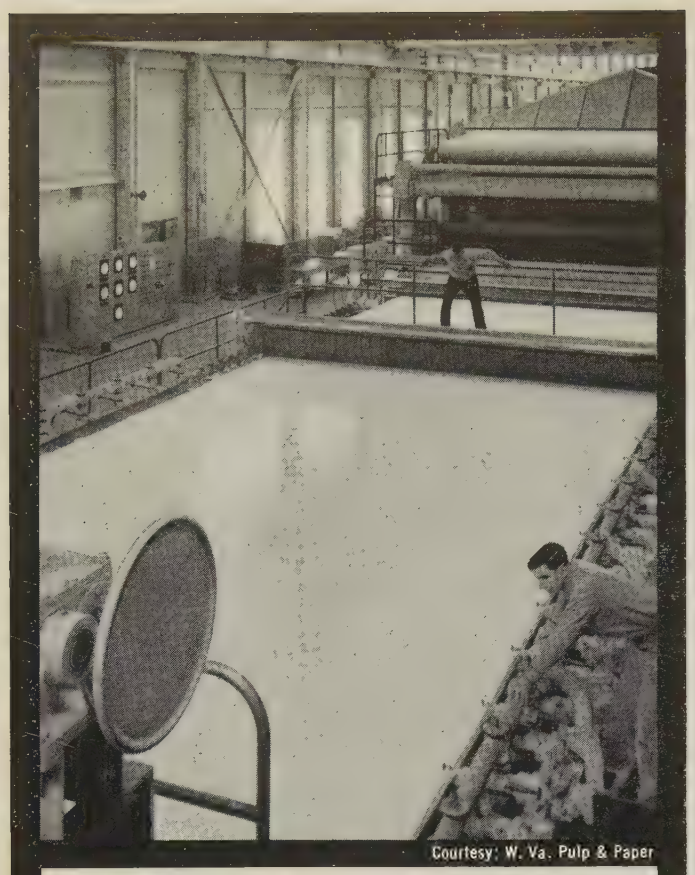
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Harold J. Schlotter, Quality Control Supervisor, Hoerner Boxes, Inc., Keokuk, Ia., a 1950 graduate of Iowa State College.

William W. Sederlund, Manager, Adhesives Technical Service, National Starch Products, Inc., New York, N. Y., a 1938 graduate of Rensselaer Polytechnic Institute.

James J. Shipman, Director, Techical Research, Kimberly-Clark Corp., Neenah, Wis., a 1940 graduate of Massachusetts Institute of Technology.

Peter H. Smeallie, Secretary, Smeallie & Voorhees, Inc., Amsterdam, N. Y.

Lawton Smith, Student, Western Michigan College, Kalamazoo, Mich.

Mauri A. Soininen, Design Engineer, Valmet Oy Aircraft Factory, Tampere, Finland, a 1950 graduate of the University of Abo.

Donald H. Sottung, Student, University of Massachusetts, Amherst, Mass.

Cyrus E. Sroog, Research Supervisor, E. I. duPont de Nemours & Co., Inc., Buffalo, N. Y., a 1950 graduate of the University of Buffalo with a Ph.D. degree.

Warren B. Stanton, Salesman, Wyandotte Chemical Corp., Wyandotte, Mich., a 1949 graduate of Princeton University.

Wesley C. Stevens, Sulphite Superintendent, International Paper Co., Chisholm, Me., a 1932 graduate of Norwich University.

Joseph C. Theiler, Assistant Project Manager, National Container Corp., Tomahawk, Wis., a 1949 graduate of Marquette University.

Lincoln R. Thiesmeyer, President, Pulp and Paper Research Institute of Canada, Montreal, P. Q., Canada, a 1928 graduate of Wesleyan University, with a Ph.D. degree from Harvard University in 1937.

Ralph A. Traill, Assistant to Manager, Wiggins, Teape & Co. Ltd., Exeter, Devon, England, a 1950 graduate of Cambridge University.

William E. Trecker, Field Research Supervisor, Ditto, Inc., Chicago, Ill., a 1942 graduate of Wisconsin State College.

Gilles G. Vallee, Project Engineer, Sherbrooke Machineries Ltd., Sherbrooke, P. Q., Canada, a 1947 graduate of McGill University.

William E. Wassmer, Industrial Engineer, West Virginia Pulp & Paper Co., New York, N. Y., a 1954 graduate of the Polytechnic Institute of Brooklyn.

Ernest L. Wimmer, Research Manager, Charles A. Krauss Milling Co., Milwaukee, Wis., a 1948 graduate of Iowa State College with a Ph.D. degree.

William R. Zimmerman, Assistant Manager, Moraine Paper Co., West Corrollton, Ohio, a 1949 graduate of Massachusetts Institute of Technology.

TAPPI Notes

Tany Agronin is now Vice-President of Black-Clawson Co. and General Manager of Pandia Inc. Div., New York, N. Y.

F. G. Barber is now Manager of the Middletown, Ohio, plants of Gardner Board & Carton Co.

Lucien F. Barriere is now Director General of Compagnie Nord Africaure de Cellulose, Paris, France.

George C. Beatteay, formerly Sulphite Superintendent of Fraser Cos., is now Manager of Restigouche Co., Ltd., Campbellton, New Brunswick.

Peter B. Borlew advises that he is the Associate Technical Director of National Container Corp., Jacksonville, Fla., not Technical Superintendent as previously announced.

Nicholas M. Brisbois, formerly Vice-President is now Consultant for Fibreboard Products, Inc., San Francisco, Calif.

Richard W. Brown is now Head of the Process and Product Development Section of the Hammermill Paper Co., Erie, Pa.

George F. Bryant, formerly of the Union Bag & Paper Corp.,

is now Assistant to the Technical Director of Angier Corp., Framingham, Mass.

Ralph W. Buttery is now Manager of Manufacturing of Bathurst Power & Paper Co., Container Div., Hamilton, Ont.

Olin W. Callighan is now Paper Sales Manager for Minerals & Chemicals Corp. of America, Edgar Div., Metuchen, N. J.

Robert E. Cates, Technical Service Engineer for the Hercules Powder Co., has been transferred from San Francisco, Calif., to Portland, Ore.

Theodore M. Chemerys, formerly of Miami Valley Coated Papers, is now Chemist for the Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich.

Dudley F. Church is now Research Liaison Assistant for the Crown Zellerbach Corp., San Francisco, Calif.

William B. Cook, formerly of the Champion Paper & Fibre Co., is now Paper Coating Superintendent for the Minnesota & Ontario Paper Co., International Falls, Minn.

D. E. Cousins, Vice-President of Hollingsworth & Whitney Co., has been transferred from Mobile, Ala., to Boston, Mass.

William R. Czellak is now Superintendent of the Carton Plant of Gardner Board & Carton Co., Middletown, Ohio.

Roy L. Davis is now Plant Manager of the Scott Paper Co., Detroit Div., Detroit, Mich.

Roger C. Derby, Management Trainee of Champion Paper & Fibre Co., has been transferred from Canton, N. C., to Pasadena, Tex.

John E. Donahue, Techical Service Engineer of the Hercules Powder Co., has been transferred from Wilmington, Del., to Holyoke, Mass.

Merrill Edridge, formerly of the Warwick Wax Co., is now an Engineer for International Business Machines Corp., Poughkeepsie, N. Y.

Newell W. Emery, Jr., Project Engineer for the Scott Paper Co., has been transferred from Chester, Pa., to Everett, Wash.

D. B. Geffken is now General Superintendent of the Oswego Falls Corp., Fulton, N. Y.

Robert J. Gilmer, formerly of the Ontonagon Fiber Co., is now in the production planning department of the National Container Corp., Jacksonville, Fla.

J. Kenneth Graver, formerly of the Monsanto Chemical Co., is now Director of Chemical Development for General Mills, Inc., Minneapolis, Minn.

G. Rurik Gustafsson, formerly of the Finnish Paper Engineers Association, is now Technical Adviser to Telko Oy., Helsinki, Finland.

Harry E. Hadley is now Manager of all of the mills of the Gardner Board & Carton Co., Middletown, Ohio.

C. N. Hagar, Jr., formerly of the Diamond Match Co., is now Technical Director of the Westminster Paper Co., New Westminster, B. C.

Earl G. Hallonquist of the research division of MacMillan & Bloedel Ltd. has been transferred from Vancouver, B. C., to Nanaimo, B. C.

Lois V. Hans is now Chief of the Paper & Paper Products Sections, Quartermaster Research & Development Center, Natick, Mass.

W. O. Hisey, formerly of the Sandy Hill Iron & Brass Works, is now Vice-President and Production Manager of the Western Kraft Co., Albany, Ore.

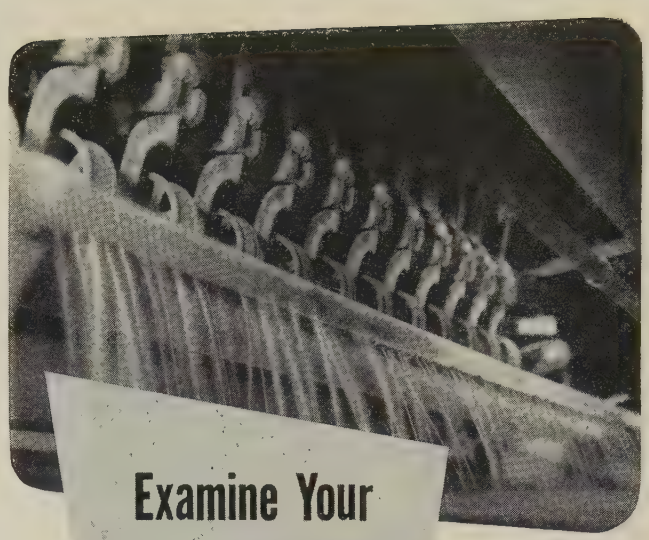
Eberhard Holzapfel, formerly of Erwin Behn Papiersackfabriken, is now Manager of Bielefelder Sackfabrik, Bielefeld, Germany.

Robert L. Leaf, Jr., is now Vice-President of the Shawano Paper Mills, Shawano, Wis.

D. Kenneth McCurdy, formerly of the Westfield River Paper Co., is now in the technical department of W. C. Hamilton & Sons, Miquon, Pa.

James H. Martindale is now Chief Engineer of the Shartle Bros. Machine Co., Middletown, Ohio.

Robert C. Montana, formerly of the Robert Gair Co., is now



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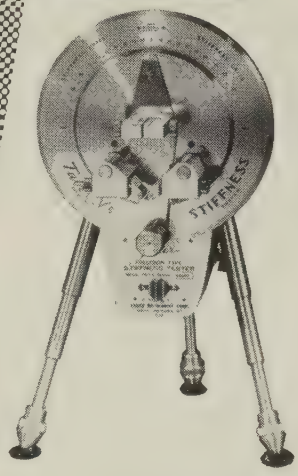

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Pacific Coast Representative
A. H. Lundberg, Orpheum Bldg, Seattle 1, Wash.

Plant Engineer for the Cornell Paperboard Products Co., Milwaukee, Wis.

Fred W. Nason, formerly of Hollingsworth & Whitney Co., is now Technical Director of the East Texas Pulp & Paper Co., Silsbee, Tex.

John H. Pearson is now Assistant Chief Engineer of Shartle Bros. Machine Co., Middletown, Ohio.

Louis J. Philipps is now Plant Engineer of the Michigan Carton Co., Battle Creek, Mich.

S. J. Quattrocchi, formerly General Superintendent of the Westfield River Paper Co., Pennsylvania mills is now with the Alliance Paper Co., Merritton, Ont.

W. Allan Schenk is now Technical Superintendent of the Hughesville and Riegelsville mills of the Riegel Paper Corp., Riegelsville, N. J.

Wesley N. Stickel is now Vice-President in Charge of Research of Texon, Inc., South Hadley Falls, Mass.

Wendell R. Tobin is now Assistant Sales Manager of the American Box Board Co., Filer City, Mich.

Alan H. Vroom, formerly of the Weyerhaeuser Timber Co., is now Assistant Director of Research of the Consolidated Paper Corp., Three Rivers, Que.

Robert E. Wagland, formerly of Samuel Jones & Co. Ltd., is now Research Chemist for the Ozalid Co. Ltd., Loughton, Essex, England.

Harvey K. Waters, Sales Engineer for the Swenson Evaporator Co., has been transferred from Harvey, Ill., to Charlotte, N. C.

Carlos Zappert is now Technical Director of Industrias Klabin do Parana de Celulose S/A, Parana, Brazil.

Piotr Zenczak, formerly a Consulting Engineer, is now with Evans Products Co., Coos Bay, Ore.

* * *

Roger Wells, Technical Director, has succeeded *C. N. Hager, Jr.*, as the official corporate representative of the Diamond Match Co. in the Technical Association.

Roy V. Weldon is now Executive Vice-President of the Great Northern Paper Co., Bangor, Me.

I. B. Purdy has succeeded *E. W. Hammer* as the official representative in TAPPI of Merritt-Chapman & Scott Co., New York, N. Y.

C. S. Conner, Manager of the Pulp and Paper Div., has succeeded *J. S. Detwiler* as the official representative in the Technical Association of the Taylor Instrument Cos., Rochester, N. Y.

C. S. Connington has succeeded *W. Charles Lodding* as the official representative in TAPPI of the Lodding Engineering Corp., Worcester, Mass.

Industry Notes

PRODUCTION

In October the paper industry shared in the general pickup in industrial activity and output for the month is estimated to have been 2,393,000 tons. This was the third largest monthly production in the history of the industry, being exceeded only by that of May, 1951, and October, 1953. There was, however, one less work day in October this year than in the other months mentioned, causing it to have the highest average daily production ever recorded. As a result, total production for the first 10 months amounted to 22,086,-132 tons and continued to lag behind last year's total by about 1%. Contrary to the experience of a year ago, the volume of new orders received rose from the September level and was, in fact, 75 thousand tons more than for that month both in 1953 and 1954.

The output of printing papers other than newsprint increased to 315,000 tons to reach its highest level since last March as this segment of the industry continued to produce in a volume approximating that achieved for the same period

in 1953. At the end of nine months production for the year at 2,678,000 tons was slightly in excess of the tonnage made for the same period in 1953. Shipments during the month are estimated to have been 314 thousand tons. The volume of orders received was 312 thousand tons, causing the backlog of unshipped orders to diminish slightly to 298 thousand tons.

The production of fine papers, estimated to have been 118 thousand tons, reached the highest level attained since March, 1952, when, presumably, a substantial part of the tonnage was going into distributor and consumer inventories. Currently, there is no evidence of rising inventories and production is believed to be well in balance with current consumption. New orders received during the month were 117 thousand tons and the volume of unshipped orders remained virtually unchanged at 63 thousand tons.

The output of coarse papers was 10% higher than in September as it increased to 308 thousand tons, approximating the tonnage produced in October of 1953. Although the volume of new orders did not rebound to the same extent, the 292 thousand tons represented by such orders was sufficient to maintain the backlog of unshipped orders at 139 thousand tons. For the year to date, production of these papers is 2,857,797 tons, about 1% more than for the first 10 months of 1953.

The production of tissue paper for the first time in 1954 failed to exceed that of the corresponding month of 1953 as an estimated 131 thousand tons were made. The production of 140 thousand tons realized in October, 1953, represented an all-time monthly high for the industry and the decline this year is explained in part by the fact that this year there was one less operating day. As a consequence, unless there is an upward revision of the estimated figure for this month, the margin over last year to date will have been reduced to 3.7%.

Although the production of paperboard at 1,090,000 tons in October represented an increase over September of more than 100 thousand tons, it failed by about 35 thousand tons to achieve the October, 1953, level. The volume of new orders received was encouraging, amounting to 1,077,000 tons, 40 thousand more than in October of last year. Orders on hand at the close of the month totaled 385 thousand tons, 5% less than a year earlier, when, it should be noted, a substantial decline from the September high had occurred.

Production and shipments of newsprint in North America during November, 1954, amounted to 628,588 tons and to 650,914 tons, respectively, compared with corresponding totals of 565,561 tons and 582,297 tons in the same month of 1953. North American production in November, 1954, was the second highest monthly total on record while shipments exceeded the levels of any previous month. Output in the United States was 106,479 tons—the largest November volume in 25 years—and shipments were 107,920 tons while Canadian (including Newfoundland) production amounted to 522,109 tons—the peak November record to date—and shipments totaled 542,994 tons.

Through the end of November this year United States mills turned out 80,558 tons or 8.1% more newsprint than in the first eleven months of 1953 while output in Canada also was 236,117 tons or 4.5% greater than in the corresponding period of last year, thus the total continental increase amounted to 316,675 tons or 5.1%.

Estimated total production for the pulp and paper industry in 1954 was 26,300,000 tons, less than 1% short of the 1953 record. Wood pulp exports rose from 162,000 tons in 1953 to 400,000 in 1954, while paperboard exports increased 30% to 610,000 tons. Improved economic conditions in many foreign countries brought about an increase in the world demand for pulp and paper.

Wastepaper

A greater tonnage of old corrugated wastepaper was con-

Statistical Highlights

Item and unit	First 9 months 1954[a]	1953	1952	% change 1954 vs. 1953	1954 vs. 1952
Pulpwood:					
Receipts, 1000 cords	20,691	20,722	20,683	− 0.1	..
Consumption, 1000 cords	21,548	21,021	19,731	+ 2.5	+11.2
Inventories, 1000 cords	4,792	5,628	6,007	− 14.9	−20.2
Wood pulp (total integrated and market):					
Production, 1000 short tons	13,438	13,091	12,259	+ 2.7	+ 9.6
Imports, 1000 short tons	1,500	1,622	1,347	− 7.5	+11.4
Exports, 1000 short tons	304	98	176	+210.2	+72.7
New supply,[b] 1000 short tons	14,634	14,615	13,430	+ 0.1	+ 9.0
Consumption, total, 1000 short tons	14,571	14,565	13,369	...	+ 9.0
Paper and board, 1000 short tons	14,016	13,956	12,823	+ 0.4	+ 9.3
Non-paper, 1000 short tons	555	609	546	− 8.9	+ 1.6
Inventories, total, 1000 short tons	742	744	743	− 0.3	− 0.1
Pulp mills, 1000 short tons	166	147	134	+ 12.9	+23.9
Paper and board mills, 1000 short tons	502	518	517	− 3.1	− 3.0
Non-paper mills, 1000 short tons	74	89	92	− 16.9	−19.7
Market wood pulp (at paper and board mills):					
Receipts, 1000 short tons	1,797	1,855	1,648	− 3.1	+ 9.0
Consumption, 1000 short tons	1,811	1,865	1,661	− 2.9	+ 9.0
Inventories, 1000 short tons	357	382	368	− 6.5	− 3.0
Market wood pulp (at non-paper mills):					
Receipts, 1000 short tons	538	595	561	− 9.6	− 4.1
Consumption, 1000 short tons	555	609	546	− 8.9	+ 1.6
Inventories, 1000 short tons	74	89	92	− 16.9	−19.7
Waste paper:					
Receipts, 1000 short tons	5,960	6,377	5,645	− 6.5	+ 5.6
Consumption, 1000 short tons	5,991	6,474	5,734	− 7.5	+ 4.5
Inventories, 1000 short tons	419	429	497	− 2.3	−15.6
Paper and board production, total	19,674	19,915	18,004	− 1.2	+ 9.3
Paper, 1000 short tons	8,624	8,470	8,182	+ 1.8	+ 5.4
Paperboard, 1000 short tons	8,840	9,237	7,799	− 4.3	+13.3
Wet machine Board, 1000 short tons	99	120	100	− 17.5	− 1.0
Construction paper and board, 1000 short tons	2,111	2,088	1,923	+ 1.1	+ 9.8
Wholesale paper and board and products:					
Sales, 1,000,000 dollars	1,956	1,926	1,816	+ 1.6	+ 7.7
Inventories, 1,000,000 dollars	262	279	268	− 6.1	− 2.2

[a] Preliminary. [b] New supply equals production plus imports minus exports.
Source: Prepared by Forest Products Division, Business and Defense Services Administration, U. S. Department of Commerce, based on data from the Bureau of the Census and the Office of Business Economics.

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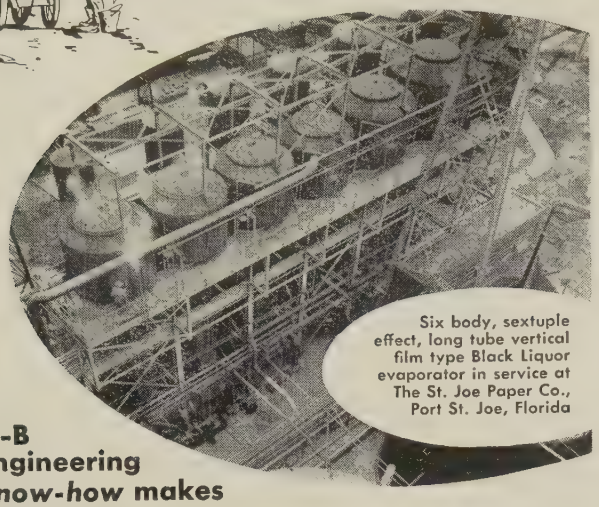

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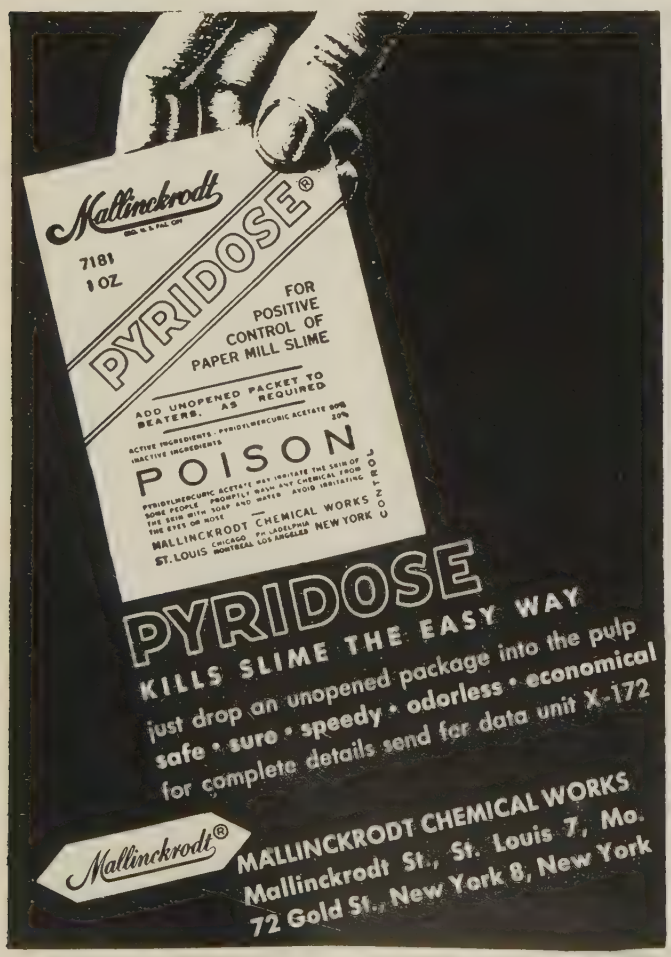
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sumed by the Eastern paperboard mills in 1954 than any of the other grades of paperstock, and, although the total wastepaper consumption for the year probably will be between 3 and 4% below that of 1953, the consumption of old corrugated will exceed that of 1953 by about 2%, according to preliminary estimates.

Containers

Production of paper milk containers increased steadily last year, production for the first nine months being about 10% above the corresponding period of 1953. Fiber can and tube production for January–September, 1954, was 16.7% below the comparable 1953 period. Folding paper box production also declined; production for the first nine months of the year was 1,780,089 tons or 3% below the corresponding period of 1953. Corrugated and solid fiber shipping container board dropped 6.1% on the same comparison basis. Bag paper production for the January–September period was 7.1% ahead of the same period in 1953, while setup boxboard was 10.1% down.

Pulpwood

In 1953 United States pulp mills consumed 28,141,000 cords of pulpwood, 85% being of softwood species and 15% of hardwood species. The greatest concentration of consumption occurred in the South where 16,198,000 cords, equal to 57% of the U. S. total, were converted into wood pulp. Mills in the South Atlantic region used 9,488,000 cords, 30% more than the combined consumption of the Northeast and North Central Regions. Florida ranked first among the individual states, using more than 2,700,000 cords.

The use of hardwood species was about equally divided between the South and the Northeast and North Central Regions, each using slightly more than 2 million cords. Hardwoods, however, were much more important as a source of fiber to mills in the latter regions, representing 25 and 37% respectively, of their requirements. In Mississippi, where a substantial quantity of hardwood is used in the production of hard and insulation board, 744,000 cords of hardwood were consumed, equal to almost half of the total quantity of pulpwood used in that state; Wisconsin ranked second, using 567,000 cords.

Wood Pulp

Total production of wood pulp for 1954 through September was 13,442,000 tons, based on preliminary Bureau of the Census data. This was an increase of 346,000 tons over production for the like period last year.

Wood pulp consumption continued at high levels during September, increasing consumption for 1954 through September to 14,020,000 tons, an increase of 63,000 tons over consumption for the comparable period last year.

Wood pulp imports for the January–September period were 1,499,804 tons, 122,000 tons less than imports for the comparable months in 1953. Overseas imports declined 157,000 tons, while imports from Canada increased 35,000 tons.

Exports continued to increase reaching their highest point in September in several years—45,000 tons. For the January–September period, exports were 274,000 tons, as against 97,000 tons in the same months in 1953.

Michigan

According to an October, 1954, press release by the Michigan Water Resources Commission, conditions in the Kalamazoo River have shown "definite improvement." The survey, which covered the river from Comstock, 5 miles above Kalamazoo, to Allegan, 40 miles below Kalamazoo, indicated the return of dissolved oxygen along sections where none was present in 1953.

The following paper companies in the Kalamazoo Valley

were given credit for instituting waste water treatment plants or other control measures which resulted in the improvement noted: Allied Paper Mills, Monarch Division, St. Regis Paper Co., Rex Paper Co., National Gypsum Co., Kalamazoo Paper Co., No. 2 Mill, Sutherland Paper Co., Divisions 4 and 7, Michigan Paper Co., Mac Sim Bar Paper Co.

Arkansas

American Forest Products Industries, Inc., 1816 N Street, N. W., Washington 6, D. C., has published a revised edition of *Arkansas Forest Facts* giving statistical information on Arkansas forests and forest industries.

Wisconsin

Wastes discharged by industries along the Fox River from Appleton downstream to Green Bay have been reduced, and satisfactory facilities or in-plant controls have been installed in the majority of instances, the Committee on Water Pollution stated recently in its official report. The committee's detailed report listed approvingly the measures taken by Consolidated Water Power & Paper Co.'s Interlake Division, Kimberly-Clark Corp.'s Kimberly Mill, and Marathon Corp.'s Northern Paper Mills Division that have reduced the discharge of sulphite liquor to the stream. Charmin Paper Mills at Green Bay was reported as in process of constructing facilities that will have a similar effect in the early future.

North Carolina

North Carolina stream condition studies preparatory to placing pollution control and abatement measures into effect have started on watersheds draining approximately two-thirds of the state, according to a report made public by the State Stream Sanitation Committee.

South Carolina

A detailed survey of Charleston harbor waters will be started early next spring by the State Water Pollution Control Authority, according to an announcement by its Executive Director, W. T. Linton.

Brazil

Brazil produced an estimated 27,600 metric tons of pulp (17,500 tons of bleached plus 10,100 tons of unbleached or raw cellulose) during the last six months of 1953. Approximately 61% of that total was produced by two mills which distribute their pulp to the domestic paper industry and the balance, or about 39%, was produced by eight plants whose total production is consumed by their respective paper manufacturing plants.

The only present project of any significance which is expected to improve Brazil's paper pulp supply portion is that contemplated by the Companhia Paulista de Celulose Copase of Sao Paulo. Present plan calls for the construction of a 200 million cruzeiro ($3,220,000) plant which will have an initial annual production capacity of 17,000 metric tons. Equipment for this projected plant is now being manufactured in France, Germany, and England.

No imports of United States pulp were recorded in 1953, the United States is listed as the third supplier during the first five months of the current year. United States shipments of pulp to Brazil during the latter period totaled 9111 metric tons, compared with 30,741 and 17,087 supplied by Sweden and Finland, respectively.

Total Brazilian production of paper increased approximately 11% in 1953 when it was 291,415 metric tons over 1952 when it was 261,883 metric tons.

Finland

An increase of approximately 20% in timber prices over

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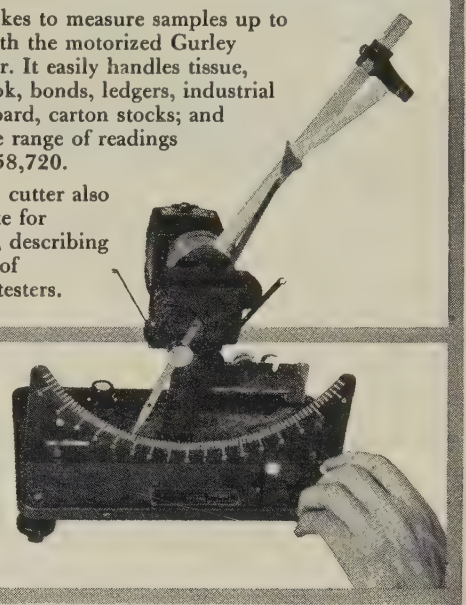

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last year was observed in the annual timber auction held at Aulanko. (At this auction the forestry administration puts up for sale timber from State-owned land in southern and central Finland.) This year total sales represented 13.5 million cubic feet of sawlogs at an average price of 120 Finnmarks (U. S. $0.52) per cubic foot. Prices ranged from 20 to 25% above those at last year's auction but timber prices last year firmed up somewhat during the fall so that the rise in prices is not quite as striking as would seem at first glance.

Pulpwood prices rose during the course of 1954. Last winter semibarked pulpwood was being offered at $10 per cubic meter, rising to $10.50 during the spring. Now the price has risen to $11 and $11.50, and the timber trade predicts that sales will soon be concluded at $12.

Germany

The only paper and board mill in Berlin, the "Gottwald & Co., Karten und Papierfabrik Gmbh," completed construction and began full operation during the early part of August, 1954. The plant has been converted from a large prewar steam turbine electric plant with substantial assistance from the European Recovery Program.

Initial wrapping paper production, derived largely from the re-pulping of waste newspapers, began in April, 1954, and has gradually increased to the present rate of 25 metric tons daily or 600 tons monthly of which 60% is sold to West Berlin wholesalers and the balance exclusively to the German Federal Republic. Exports to Denmark and Latin America are expected if current negotiations succeed.

All the demand of the West Berlin corrugated cardboard and paper bag manufacturers will be entirely covered by the Gottwald paper mill. The new board machine turned over on August 10, after several weeks of trimming, and the output is growing steadily from a 20 to a 30 tons daily average, approaching its rated capacity of 45 tons. Space has been provided for a third paper machine if the demand justifies such an expansion in the future.

The market for wrapping paper and cardboard is considered very favorable because a considerable upward trend for package material has been observed during recent years, both in Berlin and in Western Germany. The prewar annual consumption of paper amounted to 42 kg. per capita in Germany, the present consumption per capita being about 40 kg. in the Federal Republic. If the paper consumption of a country is a sound criterion for the standard of living of the population, Western Germany ranks high since its paper consumption is only exceeded in Europe by Sweden, averaging 72 kg. per capita, and by Switzerland averaging 56.5 kg. per person. Taking a normal peaceful development into consideration it may be expected that the paper consumption in Germany will increase in the next few years and the Gottwald paper mill will have a very good market for its products.

India

Mysore Home and Industries Minister, H. Siddaveerappa, has commissioned an additional paper mill at the Mysore Government-aided Mysore Paper Mills Ltd. at Bhadravati, Mysore State. With the commissioning of the second mill, identical with the original, annual paper production will be doubled to 8000 tons.

The State Government-aided Mysore Paper Mills Ltd. at Bhadravati, Mysore State, was established in 1936 to produce 4000 tons of paper (plain white, creamlaid, bond, and wrapping paper) per annum from a single machine, obtained from Germany. A second identical machine, also ordered from Germany, was being erected in March to double production capacity to 8000 tons of paper per annum.

Pakistan

A newsprint mill is being planned for the Kaghan Valley by

the Pakistan Industrial Development Corp. in consultation with Sandwell and Co. of Vancouver, Canada. Raw material for the mill will be pine from Kaghan, Chitral, Swat, and Kashmir. The corporation is also putting in a mill near Khulna, to use softwood from Sunderbun to produce 30,000 tons of newsprint per year. The two proposed mills will meet the country's present newsprint requirements.

New Zealand

Tasman

The public issue of stocks and bonds by the Tasman Pulp and Paper Co. has been successful. The demand for stocks far exceeded the £500,000 ($1,390,000) placed on the market and the company will allocate shares to applicants. The public took up £1,800,000 ($5,400,000) of the £2,000,000 ($5,560,000) bond issue before it closed, with the remaining £200,000 ($556,000) subscribed by the underwriters who disposed of it without difficulty. The success of these issues had been expected. The wide demand on the part of the general public as well as large investing institutions reflects the favorable assessment of Tasman prospects by the financial market. This call for stocks and bonds in the company was particularly indicative of public interest in a country where the capital market is not highly organized, and where there has been an apparent scarcity of capital finance recently. Almost the entire issue of both types of paper was subscribed within New Zealand. A negligible quantity of bonds were taken in the United Kingdom and a small portion in Australia.

Murupara

An agreement in principle had been reached in October with Albert E. Reed and Co. of London, British producers of newsprint and pulp products, whereby that firm would subscribe £1.5 million of the Tasman Co.'s total of share capital (common stock) of £6 million. The London firm will participate actively in the management of the Tasman Co. through membership on the board of directors and Reed Co. technical personnel who will contribute the experience and skill required to operate the enterprise successfully. One of the Reed Co. board members will reside in New Zealand and will function as full-time director of operations for the Tasman Co.

The Tasman Pulp and Paper Co. had previously entered into a contract with the Abitibi Power and Paper Co. of Canada to assist in starting the operation of the mills at Kawerau, but this is a temporary arrangement for about an 18 months' period. The association with Albert E. Reed is to be a continuing one.

Sumatra

The construction of a paper mill at Takengon, Atjeh, will be started in January next year under the supervision of the Bank Industri Negara.

The plan on the paper industry is said to have been completed and will be carried out by a Swedish company, K.W.M. It should be noted that FAO representatives, Messrs. Von Monroy and Maronne, have observed the possibility for the paper industry at Takengon. They were of the opinion that Takengon with its 100,000 ha (247,000 acres) of pine forests will be a suitable center of the paper industry.

Sweden

Pulpwood

As usual, considerable public attention has been focused on the prices bid on the parcels of standing timber offered for sale at the Crown forest auctions that commenced at Umea in North Sweden on October 11. The preliminary reports on the results in Norrland show that the prices bid averaged 34.54 crowns ($6.67) per cubic meter solid measure, or 3.2% above the average of 33.46 crowns ($6.69) for the comparable auctions in the autumn of 1953. The highest average was

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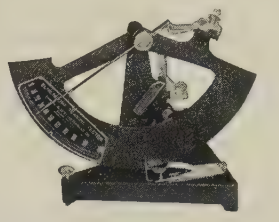

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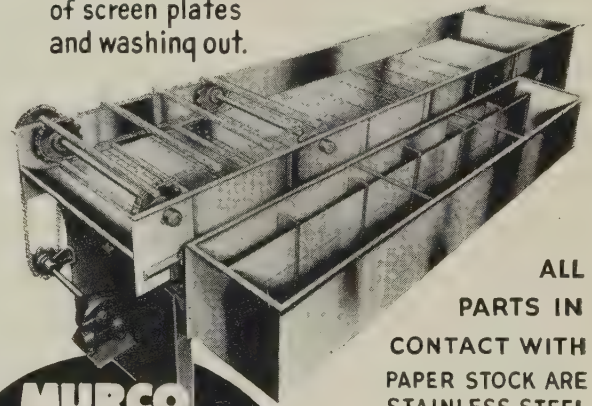

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recorded in the Falun district (43.10 crowns) ($8.62) and the lowest in the Lulea district of the far north (26.71 crowns) ($5.34).

Wood Pulp Exports

Swedish pulp shipments to the United States in August and September were much smaller than they were a year ago. This declining trend is likely to continue due partly to the higher prices obtained for Swedish pulp in the European market. Largely as a result of this price differential, the mills shipping pulp to the United States are now mainly confined to companies with a long-range interest in maintaining a foothold in the American market, and to those producing special grades of chemical pulp.

Paper and Board Exports

The foreign market for Swedish paper and board has been growing steadily stronger and both output and exports of most grades increased during 1954. This is especially true of kraft and sulphite wrapping paper, as well as paperboard of almost all types. Most paper mills have order books permitting three months of production at capacity, and export prices are firm. Aside from the declining market for Swedish paper in the United States, the general market outlook is very favorable and most mills hope to attain record sales in 1954.

TANGANYIKA

A plant for the extraction of cellulose fiber from *Andansonia Digitata* (baobab or monkey bread tree) has been erected at Lindi, Southern Province, Tanganyika. The name of the newly organized firm is Cellulose Fibre (Tanganyika) Ltd. The industrial plant has been set up in accordance with a process developed by David Oberstein, a director of the company. The plant installation is virtually now complete; it lacks only one machine—a purifier—which is en route from Scotland. It is expected that the factory will turn out 400 tons of cellulose fiber per month when in full production.

An approximately 350-man labor force will be involved in the Lindi operation. The majority of the men will be working on the extraction of the fiber from the standing baobab tree, which still remains a hand operation. Some years after the fiber is extracted, the standing tree is completely re-formed and the extraction process may be repeated. New trees will also be planted from seed and they are expected to be ready for exploitation about 16 years from time of planting. In the event that this project proves as successful as foreseen by Mr. Oberstein, it is planned that additional plants will be erected at Dar es Salaam, Dodoma, and Tanga, in that order. The head office will then be maintained at Dar es Salaam.

UNITED KINGDOM

The allowance for wood pulp imports into the United Kingdom for the first half of 1955 has been increased by £2,274,000 ($6,367,000) to £41,123,000 ($115,144,000). The allocation for the current period, July–December, 1954, was originally £35m ($98,000,000) but has been increased by supplementary allocations since the current period began to £38,849,000 ($98,777,000). Demand for paper in the United Kingdom has risen sharply during the past year and the new currency increase should enable British paper manufacturers to purchase additional raw materials for papermaking to meet the growing demand.

The currency allowance for the importation of paper and board (excluding newsprint) into the United Kingdom during the first half of 1955 will be £17,500,000 ($49,000,000), an increase of about £2,500,000 ($7,000,000) over the allowance of £15,442,000 ($43,238,000) for the second half of 1954. The Board of Trade stated that £4,000,000 ($11,200,000) of this total quota may be used to import into the United Kingdom *any type* of unconverted paper and board (except newsprint). The remainder of the allowance (about £13,500,000) ($37,800,000) may be used to import only particular types of paper and board. Due to the United Kingdom's improved balance of payments position, 20% of these individual quotas may now be spent in the dollar area.

PHILIPPINES

The Philippine papermaking industry today consists of five mills, with a total capacity of 26,000 tons a year and employing 850 workers. It is capitalized at about $4.3 million, of which an estimated 56% was supplied by private investors and the rest by the Philippine government. Local raw materials used include sugarcane bagasse, scrap paper, and lumber mill wastes.

In 1951, Philippine consumers used approximately 90,000 tons of paper and manufactures—or about 10 pounds per capita. Local production now meets about 70% of current requirements of all types of paper. The literacy of the population is increasing steadily as a result of the comparatively recent emphasis on education, and paper consumption should grow with the growth in the reading public.

A recent survey made by the Philippine Council for the United States Aid sets out the following statistics on paper production:

Type	1951 Volume	1951 Value (dollars)	1952[a] Volume	1952[a] Value (dollars)
Writing papers (tons)	4,263	2,272,337	4,700	2,366,309
Chipboard (tons)	1,566	359,586	3,860	745,122
Stencil paper (quire)	...	...	10,000	16,000

[a] Estimated.

One Filipino plant has a daily manufacturing capacity of 15 to 20 tons of chip and liner board. The Cebu Portland Cement Co., a government-owned corporation, operates a paper mill which can turn out 40,000 multiwall paper bags every 8 hours to fill most of the demand from its cement mill.

A projected newsprint mill in the southern island of Mindanao is planning auxiliary facilities which would permit the annual production of 16,500 tons of kraft liner board, 14,500 tons of kraft bag and wrapping paper, and some 12,500 tons of writing and printing papers. There are also plans for a factory to produce wrapping paper from bamboo and rice straw which abound in this country.

The present Philippine demand for newsprint is roughly 20,000 metric tons a year. Newsprint is not yet manufactured locally and supplies must be imported from abroad, largely from the Scandinavian countries, the United States, and Canada. Canadian exports of newsprint to this market have risen substantially in recent months—for the first six months of 1954 they reached a value of $527 thousand (about 93,864 cwt.), compared with $94 thousand (16,000 cwt.) in the first half of 1953.

The Soriano interests contemplate establishing a pulp and paper mill in Surigao province in the island of Mindanao. With other paper products, the mill is expected to produce 18,000 tons of newprint a year, using wood waste from a near-by lumber mill for pulpmaking. It is estimated that this project, which includes the exploitation and development of pyrite, limestone, coal, water, and power resources, will require a capital investment of $25 million.

All types and grades of paper of United States origin enter this country free of duty in accordance with the terms of the United States-Philippines Trade Agreement of 1946 (so-called Bell Trade Act), which has been extended to December 31, 1955.

The Philippine customs duties levied on paper other than from the United States vary from 10 to 20% ad valorem, depending on the kind of grade. An exception is newsprint, which can be imported into this market free of duty, regardless of its origin.

In the field of "big business," paperboard is a relative newcomer. Yet today our industry is rapidly moving into large figures, and at a rate seldom experienced even in this country of superlatives. Last year, for example, the industry produced a record 12,500,000 tons of paperboard. For the past 10 years, the increase has been at an average rate of almost 500,000 tons annually. James E. Gates, a leading economist in this field, estimates that the production of paperboard will reach 17,000,000 tons in 1960 and 26,000,000 tons in 1980.

It is a remarkable fact that our growth continues through bad times as well as in periods of prosperity. Our strength lies in the diversity of products packed in paperboard. Even in a depression, people go on buying food, drugs, cosmetics, and all the other essential supplies, most of which are now marketed in our packages.

We might shrink at the idea of having to convert and sell an additional 500,000 tons every year except for three facts which should never be forgotten:

1. The increasing U. S. population, which is estimated at 34 million for the next 20 years, with Canada expected to make similar or greater percentage gains.
2. The increasing efficiency of this population, which means greater buying power of packaged goods.
3. The development of new uses for our product.

Items 1 and 2 involve a study of statistics. These are important, especially to the professional economist, but no. 3 is the one we want to talk about now.

The development of new uses has always been a lifesaver to our industry, especially when it seemed that we were beginning to overproduce. Past examples are canned lubricating oil, bottle carriers, canned beer, furniture and radio—to name a few. Present and future new uses include packaging for supermarkets, television, fresh fruits and vegetables, foil-lined cartons, sheet fed gravure, air cargo, special food boards, boxes for "massive" merchandise, and many others.

A cynic could well accuse us of being a "lucky industry." Forty years ago, we thought Mason jars, packaged cereals, and a few items such as crackers in folding cartons might saturate our tiny production. World War I showed that paperboard offered a logical answer for critical material shortages. Canned goods were shipped to France in corrugated boxes. When the war was over, most of the new users of our product saw no reason to go back to the old-fashioned package. This resulted in a great increase in the demand for boxboard, folding cartons, and shipping containers. Then came the familiar specter of overproduction as everyone in our industry rushed in to meet these new demands.

This was duplicated to a much greater degree by World War II. Again, the danger of too much paperboard after the war might have caused the pessimist to start figuring, but before he could prove his point, other great new fields opened up for the use of paperboard products. Was this "luck" or was it the result of hard work? The actual facts prove that luck played a very minor part.

It would take too much space here to recount all these new product developments although we will refer in some detail to one typical example—fresh fruit and vegetable packages—a little later on. Suffice it to say that none of these new outlets for our expanding production was just dropped in our lap, but instead were the result of painstaking and unheralded research. Many test shipments were made, new packages were invented and discarded. Railroad regulations had to be amended, and the buying habits of the public had to be studied. Artists sit up nights improving the appearance of the folding carton because the loneliest selling job in the world is this package standing on a supermarket shelf—no father, no mother, no rooting section. It simply has to sell itself in the face of the fiercest competition to right and to left.

This creative work and study of product development goes on today at a greatly increased rate. In our industry, there

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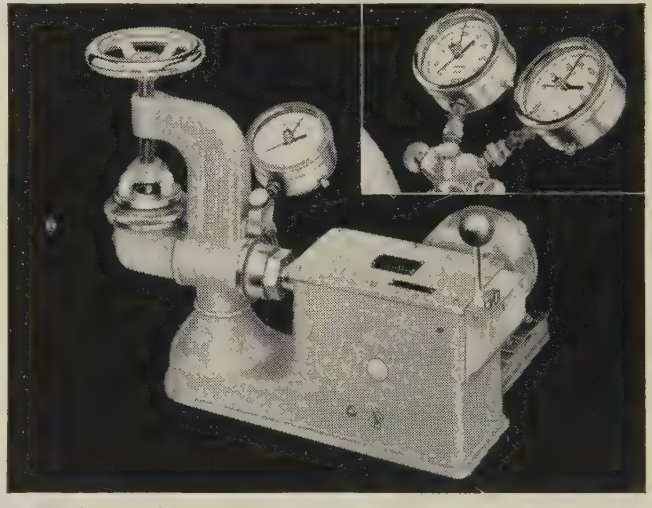

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have never been so many artists, designers, research departments, and students of merchandising. Training courses for new employees are multiplying. Our technical staffs are improving our raw materials, our production men are constantly developing better factory practices and, most important, our executives realize that these additional expenses are imperative if they want to keep ahead.

Thirty years ago Gair, and its competitors, had no technical staff to speak of. We used to call it "overhead" and "burden" —still expressive words to the hole-in-the-wall boxmaker. But today this expense item may mean the difference between profit and loss. Gair employees can today feel reassured of the company's future when they read in the *Gair News* such articles as the description of Haverhill's new laboratory and all the other technical and design departments maintained and expanding at the various divisions.

Our industry has always grown faster than the population. Our chief guarantee that this rate of expansion will continue is the increasing development of new products and new uses for paperboard. In 1900, the per capita production of paperboard was 11 lb.; in 1940, it was 100 lb.; today, it is 175 lb. The average American uses up 746 paperboard containers or packages each year—more than his average number of telephone calls.

—by J. D. Malcomson in *Gair News*, Christmas, 1954.

The Folding Carton

The Folding Paper Box Association of America has published a revised edition of its industry manual, *The Folding Carton*, available at $1.25 per copy from the FPBAA, 337 W. Madison St., Chicago, Ill.

Water Quality Criteria

The State Water Pollution Control Board of California, 721 Capitol Ave., Sacramento 14, Calif., has published an addendum to its publication, *Water Quality Criteria*, in order to bring the 1952 edition up to date.

Paper Patent Abstracts

The final book in the 1954 series of seven new Government publications containing abstracts or brief descriptions of Government-owned inventions is available at $1.00 per copy from the office of Technical Services, U. S. Dept. of Commerce (Room 6227), Washington 25, D. C. The new book, entitled *Ceramic, Paper, Rubber, Textile, Wood and Other Products and Processes*, lists 308 abstracts describing patented inventions applicable to the several fields included in the title.

New Semichemical Pulp Mills

Prairie States Paper Mills, Inc., Joliet, Ill., recently started up their neutral sulphite semichemical pulp mill. The pulp is used in corrugating board. The system consists of a Globe rotary digester, Pressofiner, and Sprout-Waldron 36-2 refiner. Seb Steffes, formerly general superintendent of Otsego Falls Paper Mills, Inc., is the superintendent.

St. Lawrence Corp., Ltd., Red Rock, Ontario, Canada, recently started up a 100-ton unbleached soda semichemical pulp mill. The pulp will be used primarily in corrugating board. The system consists of a Chemipulper, Live Bottom Cyclone, and two Sprout-Waldron 36-2 refiners.

St. Lawrence Corp., Ltd., East Angus, Quebec, has started up its semichemical pulp mill. The pulp will be used in kraft grades, especially gumming. Later a plant for semibleaching will be installed. The system consists of tumbling digesters (formerly used for kraft pulping) blow tank, Sprout-Waldron 36-2 refiner, Cowan screen, and Cowan decker.

Fitchburg

Fitchburg Paper Co., Fitchburg, Mass., has ordered a Sandy Hill Rotoformer to replace the fourdrinier section of one of its five paper machines. The Rotoformer is neither a cylinder nor a fourdrinier but a combination of both.

Mando

The Minnesota and Ontario Paper Co. is planning the addition of a high-speed newsprint machine having an annual capacity in excess of 80,000 tons of newsprint.

S. D. Warren

The S. D. Warren Co., Boston, Mass., is producing a new folding carton stock LusterBoard, said to combine in a solid board the finest coated printing surface, excellent strength, rigidity, and the superior folding characteristics of a semibleached kraft board.

KVP

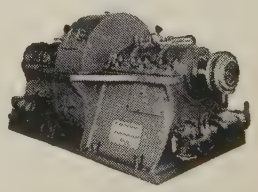
The Kalamazoo Vegetable Parchment Co., Kalamazoo, Mich., announced in its 1954 annual report that its power plant facilities are to be rebuilt within the next 2 years. The power plant, located at Parchment, Mich., will be equipped with a new high-pressure boiler and a 7500-kw. turbo-generator at a cost, with auxiliary equipment, of about $2,035,000.

Champion-International

The Champion-International Co., Lawrence, Mass., recently dedicated its new debarking plant at Bow, on the outskirts of Concord, N. H. The plant was designed to debark birch, beech, maple, and oak from woodlot owners in the surrounding area, and represents the culmination of the company's program of meeting its entire pulpwood requirements from local hardwood sources. The company's present requirements amount to 25,000 cords per year.

The plant is equipped with an Andersson debarker, the first installed in this country, using air-activated tools to remove the bark from the wood. Another feature of the

proven by performance



The Sutherland Refiner complete continuous Beating and Refining Systems.*

SUTHERLAND REFINER

*U. S. Patent No. 2,654,295

CORPORATION

TRENTON 8, NEW JERSEY

A. B. Moody, Everett Pulp & Paper Co.

D. F. McCall, Everett Pulp & Paper Co.

operation is the company's fleet of 18 specifically designed "rack-end" pulpwood rail cars for hauling the wood from Bow to the mill at Lawrence.

Everett

Donald F. McCall has been appointed vice-president and general manager of the Everett Pulp and Paper Co., Everett, Wash., succeeding Anson B. Moody, who retired on Jan. 1, 1955.

Powell River

The Powell River Co., Vancouver, B. C., has installed a Pease-Anthony cyclonic scrubber on its sulphite acid towers. Purchased from the Chemical Construction Co., New York, N. Y., the unit was made up by Industrial Coatings, Ltd., Vancouver, B. C. It is expected that at least 90% of the SO_2 formerly released in the Jenssen tower exhaust will be removed.

Rayonier

Rayonier, Inc., has acquired 80% of the capital stock of Alaska Pine and Cellulose Ltd. from the Koerner interests and from Abitibi Power and Paper Co.

Alaska Pine plans to invest $8 million in its Port Alice, B. C., plant, and will also construct a silvichemical manufacturing unit.

John P. Hollihan has joined Rayonier as a technical service representative.

Fraser

C. T. Clark has been appointed manager of the Edmunston mills of the Fraser Companies, Ltd., Edmunston, N. B. G. C. Beatteay has been named manager of the Atholville mills of the company's subsidiary, Restigouche Co. Ltd. E. O. Houghton succeeds Mr. Beatteay as sulphite superintendent at Edmunston, and L. G. Sears becomes superintendent of the Atholville mill. H. G. Larlee has been named groundwood and wood handling superintendent at Edmunston.

Great Northern

The first phase of a record-capacity mill expansion program which is producing high-quality newsprint from hardwood in commercial volume for the first time in the industry has been put into operation at East Millinocket, Me., by the Great Northern Paper Co. This initial expansion is scheduled to add 500 tons of daily capacity to the existing mill with all equipment designed for an ultimate new daily output of 800 tons of newsprint.

Although hardwoods have been used before for kraft and other kinds of paper, Great Northern pioneered their use in newsprint by first initiating and then operating a $325,000, 50-ton per day commerical pilot chemigroundwood pulp mill which proved that a high percentage of hardwoods could be successfully used to produce fine-quality newsprint in commercial volume.

Stone & Webster Engineering Corp., named to design the precedent-setting chemi-groundwood plant at East Millinocket, was also awarded the entire expansion construction job, including the engineering and design for the steam power installation.

Great Northern was already a major producer of newsprint in New England when its latest expansion was decided upon by management in 1952. It was felt that the vast natural resources of Northern Maine could be used successfully as the basis for expanding production. The company owns more than 2,250,000 acres of timberland covered by such northern hardwoods as beech, birch, and maple that flourish alongside poplar, spruce, fir, hemlock, and cedar. Another 5,000,000 acres of wood-producing land are accessible to the company's mills.

Stone & Webster engineers began actual work on the site of the Great Northern expansion program in March, 1953. With labor comparatively scarce in sparsely settled northern Maine, a camp was laid out, including a commissary, bakery, and barracks (and a trailer park nearby) for feeding and housing what rose to a peak of 1800 men drawn from a wide area. On Oct. 11, 1954, only one week behind the schedule originally established nearly two years before, the first machine in the world designed to make newsprint at 2500 feet per minute was first turned over. Two days later, the first paper was produced. A few weeks thereafter, the new chemigroundwood digesters began operating on a regular basis. With final tests completed, volume production has just begun.

The chemigroundwood process used at East Millinocket is of entirely original design, Great Northern says, with two digesters capable of pulping a minimum of 150 tons of hard-

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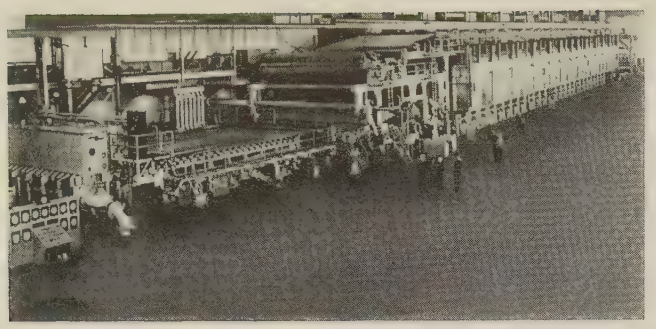
by
performance

Sutherland High Yield Kraft System*

SUTHERLAND REFINER
CORPORATION
TRENTON 8, NEW JERSEY

* U.S. Patent No. 2,591,106



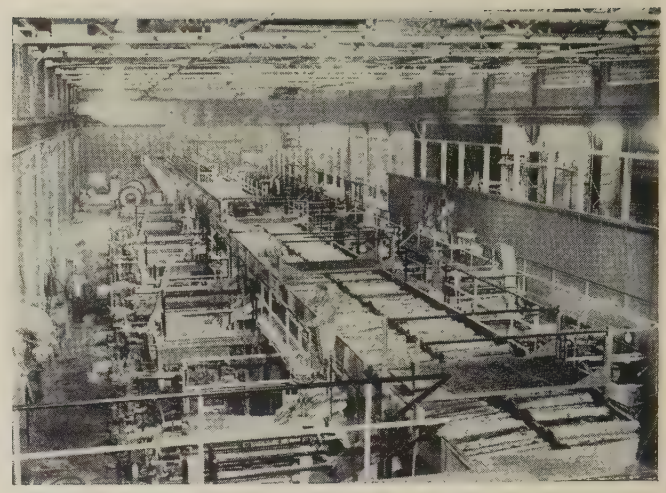
New no. 5 paper machine—lower mill

wood per day. The process, developed because of the company's confidence that it was economically and technically sound, had not been previously used commercially in any volume. Exhaustive tests showed that available hardwoods could be pulped at a substantial saving of power and that this pulp, when mixed with regular spruce and fir groundwood and sulphite pulps, would produce a paper at least equal in every respect to that already being produced by the company.

Supporting facilities of the new plant are a new woodroom, woodyard, grinder, screen, paper, and finishing rooms, train shed, machine shop, filtered water plant, high pressure steam power plant, and offices.

For a number of years the Great Northern, both through its Research and Control Department and with outside assistance, conducted an exhaustive investigation into the possibilities of expanding its production on the basis of the natural resources of northern Maine. The company owns over two and a quarter million acres of timberlands, and the wood produced by another five million acres is accessible to its mills. Millions of cords of northern hardwoods (beech, birch, and maple) as well as poplar stand side by side in these forests with spruce, fir, hemlock, and cedar. The company has developed hydro and hydro-electric installations with a rated capacity of 130,000 horsepower on the Penobscot River (one of the State's principal rivers) and, in addition, has approximately 60,000 horsepower of undeveloped sites still available on this same river.

All phases of wood utilization were considered, both in and outside the pulp and paper field. Ultimately, in the Spring of 1952, the management decided that the best choice under all the circumstances was to expand its existing mill at East Millinocket, Me., by the installation of two wide, high-speed machines designed primarily to make newsprint, and by the construction of a pulp mill designed to make pulp from hardwoods by the chemigroundwood process, and other required facilities such as an entirely new wood room, wood yard, grinder room, screen room, filtered water plant, high-pressure steam power plant, etc.



New grinder room—lower mill

Chemigroundwood

This choice was dictated by a number of considerations. The most important was that, although the chemigroundwood process had not previously been used commercially in any volume, the company's management was satisfied that this method of pulping hardwoods was economically and technically sound and offered the tremendous advantage of capitalizing on the skill and know-how incidental to 50 years of experience in making groundwood pulp. The fundamental process which was developed in the laboratories of the Syracuse University of New York for the Empire State Research Paper Associates, Inc., was thoroughly investigated and checked by the company's Research and Control Department by designing and constructing a laboratory-size pilot plant. From the outset, the tests were extremely encouraging. It was found that the hardwoods available to the company could be pulped at a substantial saving of power, and that this pulp, when mixed with regular spruce and fir groundwood and sulphite pulps, would produce a paper at least equal in every respect to that currently being made in the company's mills.

On the basis of these laboratory tests, the company, at a cost of approximately $325,000, designed and installed at the East Millinocket mill a 50-ton per day commercial pilot chemigroundwood pulp mill. This unit, which went into full-scale operation in the early Spring of 1953, demonstrated conclusively that the laboratory successes could be projected into commercial operation. In the meantime, the company's engineering department, now considerably enlarged, had gone to work preparing plans, specifications, and details for the expansion of the East Millinocket mill. At the same time,

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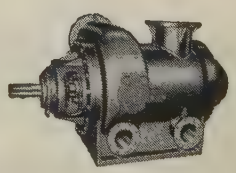

Sutherland Breaker Trap

UTHERLAND REFINER
CORPORATION
TRENTON 8, NEW JERSEY

Wood being discharged from digester after cook

Cooked wood being loaded on conveyer to grinder room

Stone & Webster Engineering Corp. of Boston was engaged as general constructors, and for the design of the high-pressure power plant and chemigroundwood pulp mill.

The Expansion

The expansion, scheduled for two steps, was designed to add 500 tons of daily capacity to the existing mill with all equipment, pipe lines, pumps, etc., sized for a future ultimate of 800 tons of new daily capacity when the machines attained the maximum speed of 2500 feet per minute for which they were designed. In the first step, a 276-in. Beloit paper machine trimming 256 in. would be installed, together with a chemigroundwood mill of entirely original design with two digesters capable of pulping a minimum of 150 tons of hardwoods per day. Other supporting facilities would be a complete new wood room, wood yard, grinder room, screen room, paper room, finishing room, train shed, machine shop, filtered water plant, high-pressure steam power plant, and offices. The completion of the first step, which included all of the necessary new buildings for the entire expansion, was scheduled for late Fall of 1954. In the second step, another new Beloit machine with a 290-in. wire trimming 270 in. would be added by the Fall of 1955, with necessary additional digesters in the chemigroundwood plant, additional grinders, additional screening capacity, an additional high-pressure boiler and other supporting facilities.

Construction

On March 2, 1953, four men from Stone & Webster started work. Soon the work forces, multiplied a hundred-fold, had built temporary buildings for offices, warehouses, shops, etc., as well as a huge silo for storing cement, a batching plant for mixing concrete, and a pipe fabricating shop. In order to provide for the great influx of workmen, a camp area consisting of a commissary, bakery, and barracks for the feeding and housing of hundreds of workers was built. In addition to the barracks, housing 400 men, the company built a modern trailer park a few miles from the construction site where at one time 89 families were housed.

Before very long all available labor from this rather sparsely settled area of northern Maine had been recruited and the call for additional men was sent out. Bricklayers came from all over New England, pipefitters fron as far as Pennsylvania, and supervisory personnel from California, Texas, Washington, and Canada. At one time a peak of 1800 employees were on the job.

By the Fall of 1953, the new wood room and conveyor system had been completed and were used in barking and piling out the winter pulpwood piles. Work on the brick walls of the new grinder room and machine room was continued throughout the winter by protecting the walls in heated temporary enclosures. Frozen ground was thawed with live steam so concrete foundations for grinders and motors and the big chemigroundwood plant could be poured. Meanwhile the steel and aluminum boiler house had been erected and enclosed, and the intricate work of assembling the boiler begun. The old wood room was rebuilt into a new and modern enlarged water treatment plant and the south half of the old screen room was reconstructed. At the same time the existing mill, barricaded behind temporary structures, crisscrossed by temporary air, steam, and stock lines, welding cables, etc., and hampered by the large crews of carpenters, masons, and engineers, struggled successfully to maintain its regular production. The winter snow melted away, leaving

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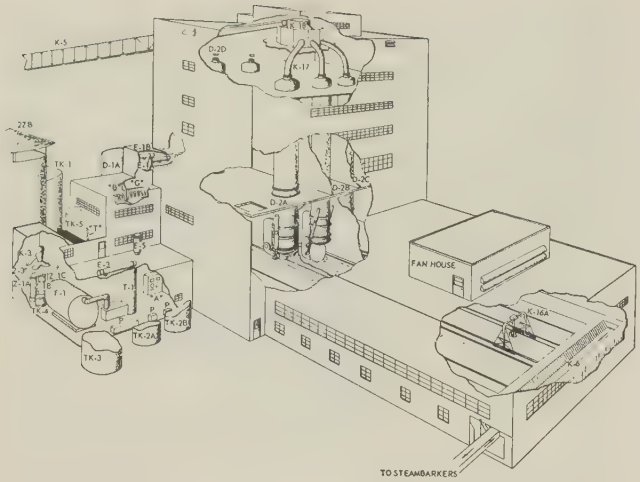
by
performance

Sutherland Inc. Pressure Washing*
Sold and Serviced by

PRESSURE · WASHING

SUTHERLAND REFINER
CORPORATION
TRENTON 8, NEW JERSEY

*U. S. Patent No. 2,355,091



MAJOR EQUIPMENT

D-1A	Accumulator	TK-1	Soda Ash Slurry Tank
D-2A,B,C,D	Digesters	TK-2A,B	Sulfiting Tanks
E-1A,B	Cook Liquor Heaters	TK-3	White Liquor Storage Tank
E-3	Accumulator Blowdown Condenser	TK-4	Liquid Sulfur Tank
E-5	Absorption Tower Condenser	TK-5	Water Storage Tank
F-1	Sulfur Burner	Z-1A,B,C	Oil Sulfur Melters
K-3	Sulfur Melter Conveyor	2ZB	Sulfur Sud
K-5	Digester Loading Conveyor	Z-3	Sulfur Melter Hopper
K-6	Cooked Wood Conveyor	"P"	Pumps
K-16A	Cooked Wood Crane & Grapple	"T"	Transformer
K-17	Log Chutes	"A"	Motor Control Panel
K-18	Log Chute Turntable	"B"	White Liquor Control Panel
T-1	Absorption Tower	"C"	Digester Control Panel

Chemigroundwood plant

the mud of the Spring thaw. Through this and the wettest summer in the memory of the old timers, 55 trucks, 14 cranes, 7 bulldozers, dozens of welders, compressors and pumps, hundreds of men pushed, scraped, lifted, and hauled for four and a half million man hours without a fatal or permanent disability accident. In June of 1954 the filter plant was placed in operation. In August the new boiler was fired. In September the 12,500-kva. high-pressure turbine went on the line.

In Beloit, Wis., meanwhile, the first of the new paper machines was being made, piece by piece, assembled, disassembled, crated, and shipped to East Millinocket. First came some of the drier rolls, cast one by one specially to dry a roll of paper 256 in. wide. Day by day the different parts and assemblies arrived and were put in place. Finally, on Oct. 11, 1954 (only a week behind the schedule that had been pulled out of a hat two years before) the whole machine, the first in the world designed to make newsprint at 2500 feet a minute, was turned over. Two days later stock made in the new grinder room, was put on the fourdrinier wire and the first paper taken off the machine's dry end. A few weeks later the new vertical chemigroundwood digesters began operating on a regular basis. Step I of the program was complete. Step II is already under way.

Data on the construction and installation of all facilities are given below.

Data on East Millinocket Mill Expansion
Great Northern Paper Company

GENERAL CONSTRUCTION DATA

Excavation	183,410 cu. yd.
Fill	98,880 cu. yd.
Concrete	48,401 cu. yd.
Steel (Struct.)	5788 tons
Steel (Reinf.)	1690 tons
Conduit (Elect.)	53.9 miles
Wiring (Elect.)	209.7 miles
Bearing Piles	1.5 miles
Log Conveyors	1.4 miles
Underground Piping	4.5 miles
Log Storage Area	1,080,000 sq. ft.
Railroad Spur Track	1.7 miles
Siding (Building)	88,265 sq. ft.
Oil Storage Tank	55,000 bbl.
Brick	2,787,000
Concrete Block	32,345 sq. ft.
Instrument Piping	10.4 miles
Instrument Valves	1000
Instrument Air Piping	2.5 miles
Instrument Fittings	25,000
Transite Pipe (Installed)	4.3 miles
Total Man Hours Step I	4,275,000 hr.

WOOD AND GENERAL YARD

Construction

Cut	74,100 cu. yd.
Fill	41,550 cu. yd.
Concrete	3450 cu. yd.
Bearing Piles	7650 lin. ft.
Log Conveyors	7000 lin. ft.
Underground Piping	4.5 miles
Log Storage Area	1,080,000 sq. ft.
F. I. A. Coverage	4,535,200 sq. ft.
Railroad Spur Track	8715 lin. ft.
Conduit (Elect.)	13.4 miles
Wiring (Elect.)	25.9 miles
Total Graded Area is in excess of	50 acres

Installed Capacities—Step 1

Woodyard

Double wing Link-Belt traveling stacker for 70-ft. piles, woodyard to hold about 70,000 cords in two piles. 80 cords per hour capacity of system. 1900 feet of 36-in. flat belt conveyor serves the stacker and the mill grinder room. 150-foot, two-strand chain conveyor loads the belts from the woodroom.

Reclaiming from piles by crane and grapple onto portable chain conveyors feeding the belts.

Hardwood

Single wing Jeffrey traveling stacker, rated capacity 50 cd./-hr., for 60-ft. pile. Woodyard size to be determined by deliveries. 900-ft. cable and button car unloading conveyor.

150-ft. two-chain transfer conveyor.

416-ft. single-chain digester feed conveyor.

Both woodyards served by a buried system of fire protection piping (all transite pipe) and monitor nozzle towers.

Major Suppliers

Wood Yard

Link-Belt—Double Stacker, Conveyor A & B.
Bancroft & Martin Rolling Mills Co.—Conveyors.
F. N. McIntire—Brass Fittings Fire Protection System.
Johns Manville—Transite Pipe.
Goodyear Tire & Rubber Co.—Belts for Conveyors.
Jeffrey—Stacker Hardwood.

WOODROOM

Construction

Excavation	4000 cu. yd.
Fill	380 cu. yd.
Cubature	426,000 cu. ft.
Concrete	3020 cu. yd.
Steel (Struct.)	160 tons
Steel (Reinf.)	25 tons
Conduit (Elect.)	2.8 miles
Wiring (Elect.)	4.8 miles
Building Size	130 ft. 8 in. × 85 ft. $8^1/_8$ in

Installed Capacities—Step 1

Woodroom

1—Welded Barking Drum, 2 section, 12 ft. diameter × 45 ft. overall.

1—Solid Shell Riveted Drum, 4 section, 10 ft. diameter × 44 ft. overall.

Log Haul-up Conveyor from river—8-strand chain.

Drum feed and discharge conveyors—54-in. flat rubber belt.

Return conveyors, recycling wood to drums—single-strand chain.

Bark dewatering—perforated plate scraper conveyor.

Bark to truck loading—36-in. troughed rubber belt.

Capacity of Woodroom on river driven softwoods is 50–75 cords per hour depending on wood condition. Provision is made for a third drum on softwood or hardwood.

2000-g.p.m. vertical turbine type water pump installed in a basement sump to serve the building.

Major Suppliers

Woodroom

Canadian Ingersoll Rand—Welded Barking Drum.
Goodyear Tire & Rubber—Belts.
Falk Co.—Conveyor Drives.
Fairbanks, Morse & Co.—Pumps.

Bancroft and Martin Rolling Mills Co.—Steel Frames & Supports.
Pennsylvania Transformer Co.—2000-kva. transformer.
I.T.E. Co.—Switch Gear 550 volts.
Westinghouse—Control Center.
Maine Cement Products Co.—Precast Roof Slabs.
Bangor Sheet Metal & Roofing Co.—Roofing & Insulation.
General Electric Co.—Motors 550 volt.

CHEMIGROUNDWOOD PLANT

Construction

Excavation	19,925 cu. yd.
Fill	6865 cu. yd.
Cubature	1,623,975 cu. ft.
Concrete	11,150 cu. yd.
Steel (Struct.)	1200 tons
Steel (Reinf.)	627 tons
Siding	48,200 sq. ft.
Conduit (Elect.)	10.1 miles
Wiring (Elect.)	20.9 miles
Concrete Block	8600 sq. ft.
Building Sizes	
Digester Bldg.	197 ft. 0 in. × 113 ft. 0 in.
Stream Barker Bldg.	95 ft. 0 in. × 44 ft. 0 in.
White Liquor Bldg.	65 ft. 0 in. × 60 ft. 0 in.

Installed Capacities—Step 1

Chemigroundwood Plant:

Digester Plant

2—10 ft. 6 in. diameter × 60-ft. steel vertical digesters with full size flat bottom hinged door. Door operation controlled by hydraulic lifting cylinders and cylinder actuating bolts. Rated capacity, 25 cords; on 8-hour cycle, 75 cords per day.
1—17 ft. diameter × 48-ft. vertical cooking liquor accumulator.
Complete liquor charging, circulating and heating system, cycle-controlled from a graphic instrument panel.

White Liquor Plant

1—40 ft. diameter × 34 ft. steel slurry storage tank and slurrying system, including vacuum car unloading, for soda ash.
1—30 ft. diameter × 56 ft. concrete sulphur storage silo, with car unloading hopper and elevator.
2—C. I. L. sulphur meters.
1—Chemical Construction Corporation spray sulphur burner, 8 ft. diameter × 19 ft.
1—3 ft. 6 in. diameter × 13 ft. 2-in. high absorption tower, tray type.
2—12-ft. diameter × 13 ft. high sulphiting tanks.
1—25 ft. diameter × 18 ft. high white liquor storage tank.

Major Suppliers

Link-Belt Co.—Conveyors.
William Neill Co.—Sulphur Silo.
Tower Iron Works—Weigh Hopper.
Fairbanks, Morse & Co.—Scale.
Chemical Linings—Tank Linings.
Eastern Industries—Fuel Oil Pump.
Schutte & Koerting Co.—Fuel Oil Burner.
New England Lead Burning—Quench Section.
Artisan Metals Inc.—Absorption Section.
Ingersoll Rand Co.—Pumps, etc.
G. A. T. X.—Steel Tanks.
Diamond Alkali—Slurry Handling Auxiliaries.
Nash Engineering Co.—Vacuum Pump.
Bethlehem Steel Co.—2 Digesters.
Worthington Corp.—Precharge Pumps.
Air Royal Co.—High-Pressure Tanks.
Dollinger Corp.—Filters.
Lithcote Corp.—Fluid Receiver Tank.
Pathon Mfg. Co.—Hydraulic Cylinders.
Barksdale Valves—Valves.
Greer Hydraulics, Inc.—Hydraulic Accumulators.
Struthers-Wells Corp.—Cooking Liquor Heaters, etc.
Elliott Company—Cooking Liquor Twin Strainers.
Dean Brothers Pumps, Inc.—Purge Water Pump.
Yoeman Brothers Co.—Sump Pump.
Buffalo Forge Co.—Waste Gas Exhaust Fan.
W. L. Blake Co. (Ohio Injector Co.)—Motor Operated Valves.
Alloy Steel Products Co.—Motor Operated Valves.
Nordstrom—Motor Operated Valves.
Croll Reynolds Co.—Hogging Jet.
Philadelphia Gear Co.—Limitorque Operators.
Whiting Corporation—Grapple Crane.
Colson Service Co.—Digester Service Crane.
Foxboro Company–Instrumentation.
Minneapolis-Honeywell—Instrumentation.
Mason-Neilan—Instrumentation.
Westinghouse (Sturtevant)—Air Supply Fans.
Buffalo Forge Co.—Waste Gas Exhaust Fan.
Hirschman-Pohle Co.—Exhaust Fans.
Automatic Sprinkler Corp.—Fire Protection System.
Otis Elevator Co.—Elevator.
Allis Chalmers Co.—Stream Barker Pumps.
Chemical Construction Co.—Molten Sulphur Pump.
General American Transportation Corp.—White Liquor Storage tank.
Double A Products Co.—Check Valves.

GRINDER ROOM

Construction

Excavation	34,100 cu. yd.
Fill	5550 cu. yd.
Cubature	1,228,450 cu. ft.
Concrete	7850 cu. yd.
Steel (Struct.)	486 tons
Steel (Reinf.)	156 tons
Brick	515M
Siding	2565 sq. ft.
Conduit (Elect.)	5.7 miles
Wiring (Elect.)	17.6 miles
Building Size	305 ft. 0 in. × 123 ft. 2 in.

Installed Capacities—Step 1

Grinder Room:

6—Great Northern Waterous 67 × 54-in. grinders for softwood arranged in three lines driven by 6000-hp. motors of Westinghouse manufacture. 40 tons per day rating.
2—Similar grinders in one line for pretreated hardwood. 75 tons per day rating.
6—Jonsson type $^1/_8$-in. perforated bull screens, half on hardwood, half on softwood. 100 tons per day rating.
3—36 × 24 Jeffrey bull screen reject shredders.
Double softwood block tanks of 150 cord capacity feeding grinders through a water trough conveyor.
Hardwood fed to grinders by a dual, single-strand chain conveyor.

Major Suppliers

Montague Machine Co.—Waterous Great Northern Grinders and Governors.
Warren Steam Pump Co.—Grinder Hydraulic System Pumps, Stock Pumps.
Ingersoll Rand Co.—White Water Booster Pump.
Goulds Pump Co.—Reject Stock Pumps.
Bird Machine Co.—Bull Screens.
Jeffrey Manufacturing Co.—Shredders.
Westinghouse Electric Corp.—Grinder Motors, 6900-volt Transformers and Switchgear.
Whiting Corp.—30-Ton Crane.
J. O. Ross Engineering Corp.—Ventilating System (all units Sturtevant).
Foxboro Company—Process Instrumentation.
Penn. Transformer Co.—550-volt Transformer.
I.T.E. Co.—550-volt Switchgear.
G.E. Co.—550-volt Motor Control Centers and Motors.
Chemical Linings, Inc.—Tile Work.
Artisan Metal Products Co.—Fabricated Stainless Steel Pipe.
Bancroft & Martin Rolling Mills Co.—Structural and Miscellaneous Steel.
Link-Belt Co.—Dewatering Screens.

SCREEN ROOM

Construction

Excavation	1315 cu. yd.
Fill	630 cu. yd.
Cubature	1,032,550 cu. ft.
Concrete	1695 cu. yd.
Steel (Struct.)	304 tons
Steel (Reinf.)	116 tons
Brick	246M
Conduit (Elect.)	2 miles
Wiring (Elect.)	18.9 miles
Building Size	193 ft. 0 in. × 108 ft. 0 in.

Installed Capacities—Step 1

Screen Room

2—11 ft. 6 in. diameter × 20-ft. Valveless Deckers for groundwood, rated at 100 tons per day.
3—9 ft. 6 in. diameter × 12-ft. Vacuum Deckers for chemi-groundwood, rated at 60 tons per day.
8—Cowan rotary lithcoted pulp screens; 5 on groundwood (1 being a secondary), 3 on chemi-groundwood (1 being a secondary).
3—Double disk Bauer reject refiners, 2 on groundwood, 1 on chemigroundwood. Dual 300-hp. motors installed.

3—Allis Chalmers LoHed vibrating screens prethicken rejects for refiners.

Major Suppliers

Improved Machinery Corp.—Deckers, Agitation.
Montague Machine Co.—Cowan Screens.
Bauer Bros—Refiners, Centrifugal Cleaners.
Stebbins Engineering Co.—Tile.
Bancroft and Martin Rolling Mills—Structural and Miscellaneous Steel.
Ingersoll-Rand Co.—Water Pumps.
Goulds Pump Co.—Stock Pumps.
Warren Steam Pump Co.—Stock Pumps.
DeZurik Shower Co.—Consistency Regulators, Cont. Valves.
Fabri-Valve Co.—Stock Valves.
Crane Co.—Stock Valves.
Taylor Instrument Co.'s Process Instrumentation and Panel.
Minneapolis-Honeywell Reg. Co.—pH Controller.
Mixing Equipment Co.—Agitator.
Artisan Metal Products Co.—Stainless Pipe and Flow Boxes.
Portland Copper and Tank Works—Stainless Pipe Fittings.
Allis Chalmers Mfg. Co.—De-watering Pulp Screens, Electrical Transformers and Switchgear.
Penn. Transformer Co.—Electrical Transformers.
I.T.E.—Electrical Switchgear.
General Electric Co.—Motor Control Centers, a.c. Motors.

PAPER MACHINE ROOM

Construction

Excavation	24,860 cu. yd.
Fill	19,850 cu. yd.
Cubature	4,938,480 cu. ft.
Concrete	10,540 cu. yd.
Steel (Struct.)	1421 tons
Steel (Reinf.)	479 tons
Brick	1273M
Conduit (Elect.)	9.5 miles
Wiring (Elect.)	52.2 miles
Concrete Block	11,561 sq. ft.
Building Size	502 ft. 0 in. × 144 ft. 0 in.

Installed Capacities—Step 1

Paper Room:

Beloit Paper Machine:
Rated 256-in. trim, 2500 f.p.m., 400 tons/day.
Air-cushioned headbox.
137-ft. fourdrinier.
Vacuum transfer system.
Three vacuum presses, two conventional, one inverse.
54 driers (60 in.) in three sections.
Midwest Fulton Drier drainage system. Bowser forced feed lubrication.
9-roll calender stack.
Horizontal reel.
Beloit winder, rated 5000 ft./min.
Mechanical differential drive by Beloit with Westinghouse electric helper drive; through line shaft steam turbine driven; helper drive power by line shaft generators.

Fischer and Porter stock proportioning system. 10 Shartle selectifier screens as pre-cleaners. Jonsson screen for selectifier tailings. Nash and Roots-Connersville vacuum pumps. Shartle Hydrapulper, 18 ft. diameter, for dry end broke. E. D. Jones Liebeck pulper for press broke. J. O. Ross Corp. totally enclosed drier section hood and complete ventilation system including economizers. Eastwood-Nealley suction box conditioner.

Major Suppliers

Beloit Iron Works—Paper Machine 256-in. trim, Winder, Drive, Headbox.
Stebbins Engineering & Mfg. Co.—Machine Chests, Wire, Pit, White Water Tank Couch Pit.
Chemical Linings, Inc.—Liebeck Pulper Tank.
Roots-Connersville Blower Co.—Vacuum Pumps, Couch Roll.
Shartle Bros. Machine Co.—Selectifier Screens & Hydrapulper.
Fischer & Porter Co.—Stock Proportioning System.
Improved Machinery, Inc.—Agitators.
General Electric Co.—Steam Turbine, Motor Control Centers, all a. c. Motors.
Gould Pump Co.—Pumps.
Ingersoll-Rand Co.—Pumps.
Nash Engineering Corp.—Vacuum Pumps.
J. O. Ross Engineering Co.—Hood, Economizers and Ventilating System.
Whiting Corp.—Cranes.
Artisan Metal Products Co.—Stainless Steel Pipe.
Portland Copper & Tank Works—Stainless Steel Fittings.
Midwest Pipe & Supply Co.—Fabricated Steel Pipe.
Bird Machine Co.—Jonsson Reject Screen, Self-conditioners.
DeZurik Shower Co.—Automatic Valves.
Midwest Fulton Co.—Paper Machine Dryer Drainage System.
Taylor Instrument Co.—Process Instrumentation.
Bancroft & Martin Rolling Mills Co.—Structural & Miscellaneous Steel.
Westinghouse Electric Corp.—Electric Paper Machine Helper Drive.
I.T.E. Company—550-volt Switchgear.
Allis Chalmers Co.—2300-volt Switchgear.
Pennsylvania Transformer Co.—Transformers—5000 kva., 3-1000 kva.
Lapp Insulator Co.—Color Metering Pump.
Foxboro Co.—Process Instrumentation.
Bowser, Inc.—Paper Machine Lubricating System.

FINISHING ROOM AND TRAIN SHED

Construction

Finishing Room

Excavation	2970 cu. yd.
Fill	2085 cu. yd.
Cubature	738,700 cu. ft.
Concrete	2125 cu. yd.
Steel (Struct.)	333 tons
Steel (Reinf.)	32 tons
Brick	196M
Conduit (Elect.)	1 mile
Wiring (Elect.)	10.2 miles
Concrete Block	380 sq. ft.
Building Size	114 ft. 0 in. × 144 ft. 0 in.

Train Shed

Excavation	4100 cu. yd.
Fill	8400 cu. yd.
Cubature	965,600 cu. ft.
Concrete	2640 cu. yd.
Steel (Struct.)	194 tons
Steel (Reinf.)	30 tons
Brick	300M
Conduit (Elect.)	2 miles
Wiring (Elect.)	1.4 miles
Building Size	318 ft. 0 in. × 112 ft. 4 in.

Major Suppliers

Finishing Room

Conveyors, heading and wrapping machines, scales, lowerator, and roll upender bought as a completely engineered unit from Lamb-Grays Harbor Co., Inc. Rolls conveyed on troughed belts, stored on and fed from handling tables to the various stations by pushbutton control of the operators.
Clark gas powered trucks with Bartel clamp device are used for car loading.

POWER PLANT

Construction

Excavation	14,200 cu. yd.
Fill	12,200 cu. yd.
Cubature	1,822,000 cu. ft.
Concrete	3100 cu. yd.
Steel (Struct.)	1392 tons
Steel (Reinf.)	158 tons
Siding	37,500 sq. ft.
Oil Storage Tank	55,000 bbl.
Conduit (Elect.)	8.1 miles
Wiring (Elect.)	39.0 miles
Concrete Block	10,324 sq. ft.
Building Size	191 ft. 11½ in. × 144 ft. 0 in.

Installed Capacities—Step 1

Boiler House

Boiler—Capacity of 300,000 lb./hr. at 1300 p.s.i. and 855°F.
Boiler is approximately 36 ft. wide, 24 ft. deep, and 56 ft. high.
Is so designed that it will burn either coal or oil. Is now being set up for oil burning only. Present oil storage capacity will be increased by addition of one 55,000-bbl. tank.

At full rating, oiler will consume 21,750 lb. of oil per hour or approximately 2750 gal. of oil per hr.

Turbine

One 12,500-kw., noncondensing extraction turbine and generator 2400 r.p.m. 6900 volts, 3 phase, 40 cycle, hydrogen cooled steam supply 1250 p.s.i., 855°F.
Will normally have 175,000 lb. extracted at 210 p.s.i.
Will exhaust normally at 40 p.s.i.

Water Treating Plant

Consists of two essential steps.

1st step consists of color reduction, clarifying and filtering.
2nd step consists of demineralizing the water from step one.
Plant has a continuous combined capacity of approximately 250 g.p.m.
Plant is used to supply the make-up water for two 1300 lb./hr. boilers.

Major Suppliers

Combustion Engineering Inc.—Boiler.
General Electric Co.—Turbine Generator and Motors.
Cochrane Corp.—Deaerating Feed Water Heater Equipment, Blow Down Equipment, Deionizing Equipment.
Ingersoll-Rand Co.—Boiler Feed Pumps, Pumps.
Westinghouse Electric Corp.—Feed Water Heater, Ind. Draft. Fans and Motors, Switchgear, Turbine Drives for Feed Water Pumps.
The Green Fuel Economizer Co. Inc.—Forced Draft Fans.
I.T.E. Circuit Breaker Co.—Station Service Unit Substation.
Midwest Piping Co. Inc.—Steel Piping Fabricated.
Bailey Meter Co.—Combustion Control.
Milton-Roy Co.—Chemical Pumps.
Infilco Inc.—Water Clarification Equipment.
Whiting Corp.—20-Ton Turbine Room Crane.
The Chapman Valve Mfg. Co.—Steel Valves.
The Ohio Injector Co.—Miscellaneous Valves.
American Locomotive Co.—Fuel Oil Heaters.
The Griscom-Russell Co.—Suction Heater for Storage Tank.
Chicago Pneumatic Tool Co.—Instrument Air Compressor.
Warren Steam Pump Co. Inc.—Fuel Oil Pump Equipment.
Pennsylvania Pump and Compressor Co.—Miscellaneous Pumps.
The Portland Co.—Welded Steel Tanks.
Copes-Vulcan—Boiler Feed Water Regulating Equipment, Steam Desuperheating.
Edward Valves Inc.—Small High-Pressure Steel Valves, Instrument Valves.
Manning Maxwell and Moore Co.—Hancock Valves.
Bowser, Inc.—Turbine Lubrication.
Atwood and Morrill—40-lb. Relief Valves.
Farris Engineering Corp.—Safety and Relief Valves.
Carpenter and Paterson—Pipe Hangers.
Hagan Corp.—Flow Meters.
Mason Neilan Co.—Level and Temperature and Pressure Controls and Indicators.
The Swartwout Co.—Steam Pressure Reducing and Desuperheating Control Equipment.
Armstrong Co.—Traps.
Minneapolis-Honeywell Regulator Co.—Temperature Recording Instruments.

FILTER PLANT

Construction

Excavation	1140 cu. yd.
Fill	200 cu. yd.
Cubature	203,900 cu. ft.
Concrete	675 cu. yd.
Steel (Struct.)	42 tons
Steel (Reinf.)	50 tons
Conduit (Elect.)	2.8 miles
Wiring (Elect.)	8.0 miles
Building Size	118 ft. 0 in. × 48 ft. 0 in.

Installed Capacities—Step 1

Water Filter Plant

2—Raw Water Pumps, 15,000 g.p.m. (I-R Co.)
2—Fire Pumps, 2500 g.p.m., 125 lb. (Peerless).
2—Filtered Water Pumps, 15,000 g.p.m., 40 lb. (I-R Co.).
1—Wash Water Pump (I-R Co.).
Wallace and Tiernan 4000 lb./hour chlorinator.
1—Link-Belt Traveling intake trash screen, $^3/_8$-in. mesh.
9—Green Bay North Water Screens, 14 × 88 mesh.

Major Suppliers

Ingersoll-Rand Co.—Raw Water, Filtered Water, and Shower Booster Pumps.
Peerless Pump Division—Fire Pumps.
Green Bay Foundry & Machine Co.—North Water Filters.
General Electric Co.—All Motors, 600-volt Motor Control Centers.
Westinghouse Corp.—One 600-volt Motor Control Center.
Chapman Valve Co.—Intake Gates.
Kennedy Valve Co.—Motor Operated Raw Water Pump Discharge Valves.
Link-Belt Co.—Trash Screen.
Foxboro Co.—Instruments and Panel.
Wallace & Tiernan Co.—Chlorinator.
Midwest Pipe & Supply Co.—Wrought Iron and Steel Fabricated Pipe.
Allis Chalmers Co.—2300-volt Switchgear and Transformer.

MACHINE SHOP

Construction

Excavation	1200 cu. yd.
Fill	595 cu. yd.
Cubature	581,700 cu. ft.
Concrete	1390 cu. yd.
Steel (Struct.)	185 tons
Steel (Reinf.)	8 tons
Brick	220M
Conduit (Elect.)	
Wiring (Elect.)	9 6 Miles
Building Size	178 ft. 0 in. × 176 ft. 3 in.

Major Suppliers

American Tool Co.—48-in. American Lathe; 16-In. American Lathe.
Kearney & Trecker Corp.—American 4 ft. 9 in. Radial Drill
The R K LeBlond Machine Tool Co.—25-in. LeBlond Lathe. LeBlond No. 2 Universal Cutter Grinder. No. 2 CH Milwaukee Milling Machine.
The Cincinnati Milling Machine Co.—28-in. Cincinnati Shaper.
Samuel G. Rogers Co.—CC-4 Slitter Grinder.
Lobdell United Company—No. 5 GHV Roll Grinder. Roll Grinder Dust Collector.
Whiting Corporation—60-ton Crane.

STORE ROOM, OFFICE AND LOCKER ROOMS, OIL AND PAINT SHOP AND GENERAL EQUIPMENT

Construction

Office & Locker Rooms

Excavation	900 cu. yd.
Fill	500 cu. yd.
Cubature	183,600 cu. ft.
Concrete	653 cu. yd.
Steel (Struct.)	64 tons
Steel (Reinf.)	9 tons
Brick	37M
Conduit (Elect.)	
Wiring (Elect.)	0.9 mile
Building Size	116 ft. 0 in. × 53 ft. 11 in.

Oil & Paint Shop

Excavation	600 cu. yd.
Fill	75 cu. yd.
Cubature	15,200 cu. ft.
Concrete	113 cu. yd.
Steel (Struct.)	6.8 tons
Steel (Reinf.)	0.2 tons
Concrete Block	1570 sq. ft.
Conduit (Elect.)	0.1 mile
Wiring (Elect.)	0.4 mile
Building Size	36 ft. 0 in. × 32 ft. 0 in.

Installed Capacities—Step 1

General Equipment

1—1900-c.f.m., 100-p.s.i.g. Ingersoll-Rand Co. Air Compressor, After Cooler.

Whiting Cranes:

1—2, 30-ton hooks, 104-ft. span, Machine Room.
1—2, 30-ton hooks, 70-ft. span, Machine Shop.
1—1, 30-hook, 80-ft. span, Grinder Room.
1—Single-hook 15-ton gantry serving Machine Winder.
1—Single-hook 20-ton crane serving main steam turbo-generator.
Electric Distribution System; 33,000/6900/2300/575 volt.
Transformers: 33000/6900—1 rated 18/24000 kva.
6900/2300—3 rated 5000 kva.
6900/575—7 rated 1000 and 2000 kva.

Major Suppliers

Store Room

Lyon Metal Products, Inc.—Shelving and Bar Racks.
Toledo Scale Co.—Model No. 2151 Toledo Scale.
J. O. Ross Engineering Corp.—Heating and Ventilation Equipment.

CRANE & CO.

Waste treatment facilities have been provided by Crane & Co., Inc., Dalton, Mass., whose mill effluent flows to the East Branch of the Housatonic River. Settling basins are employed to remove suspended matter and an experimental

oxidation lagoon is placed in series with these. It is hoped that this unit will substantially reduce the oxygen demand of the combined effluent which contains rag and flax cooking liquors, pulp wash waters, and machine overflows.

Rhinelander

New equipment costing $40,000 has been installed to improve the results of burning of sulphite liquor at Rhinelander Paper Co., Rhinelander, Wis. Need for this developed from the company's large-scale program for utilizing sulphite liquor which formerly was discarded to the Wisconsin River.

Centrifugal fly ash collectors have just now been added to two boilers to solve a problem in the final step of this mill's sulphite utilization program. The Rhinelander subsidiary, Lake States Yeast Corp., now completely processes all collectible sulphite liquor to extract useful products, thereby keeping it out out of the stream.

First, microscopic yeast organisms are propagated in the liquor to convert its wood sugars into dried yeast valuable for human and animal nutrition and for pharmaceutical uses. Next, the desugared liquor passes through an evaporator plant that rids it of excess water, concentrating it to 50% solids and for some purposes making it into a dry powder. Then the desugared concentrate is sold to manufacturers of adhesives, dispersants, and other chemical products. Finally, any unsold concentrate is burned as industrial fuel in two specially equipped boilers, replacing coal.

Fly ash resulting from the combustion occurred in troublesome quantities at times when both of the mill's liquor-burning boilers were operating. The new equipment operates on the same general principle as a cream separator. It collects the finely divided lime ash in a hopper before the flue gas is released to the atmosphere. Collected fly ash then is disposed of along with other ash from the power plant.

Crown Zellerbach

The following management changes have been made by Crown Zellerbach Corp.: Frank N. Youngman has been elected president of Crown Zellerbach, Canada Ltd., and of the Elk Falls Co. Ltd., Robert R. Young becomes vice-president and general manager of Crown Zellerbach, Canada; in the United States, Reed O. Hunt is appointed vice-president for operations, Peter T. Sinclair becomes vice-president for manufacturing, E. A. Paul is now director of industrial relations, and E. W. Erickson assumes expanded responsibilites for over-all supervision of construction and project engineering, including the central engineering office. Herbert H. Wymore is appointed assistant to the vice-president of manufacturing, Edward H. Nunn becomes resident manager at Carthage, N. Y., Glen D. King is now assistant resident manager at West Linn, Ore., Peter T. Dickie is appointed technical supervisor at West Linn, Ray Dahl becomes assistant manager at St. Helens, Ore., and Gus Ostenson is appointed resident manager of the corporation's projected San Joaquin kraft paper mill at Antioch, Cal.

Weyerhaeuser

Weyerhaeuser Timber Co., Portland, Ore., has added a laminating machine to its Springfield, Ore., containerboard mill. The new machine will handle paper up to 88 in. wide up to a rate of 500 f.p.m.

Gould

Gould Paper Co., Lyons Falls, N. Y., has shut down its sulphite mill after 53 years of operation. Originally a milk-of-lime system, the acid plant was converted to limestone in 1918, and was later changed to a modern automatic system with hot acid facilities. In the future, Gould will purchase its requirements of sulphite pulp.

C.I.P.

Canadian International Paper Co., Montreal, Que., established an all-time record production of 845,000 tons of newsprint in 1954, reflecting partial completion of a $42 million expansion program which will boost production to 920,000 tons in 1956.

Kodak

Walter C. Nelson has been appointed superintendent of the paper finishing division of Eastman Kodak Co., Rochester, N. Y.

Hudson

A research expansion program, including construction of a new laboratory at Palatka, Fla., and purchase of a group of buildings at South Windham, Me., is being undertaken by Hudson Pulp & Paper Corp., New York, N. Y.

Beckett

The Beckett Paper Co., Hamilton, Ohio, has completed plans to install an additional 126–130 in. fourdrinier machine to produce fine printing papers at speeds up to 600 f.p.m.

Charmin

State authorities have granted Charmin Paper Mills, Green Bay, Wis., an extension of time until June 30, 1955, for completing its $2,500,000 plant for the manufacture of yeast from spent sulphite liquor.

Westminster

Westminster Paper Co., New Westminster, B. C., has appointed Charles W. Card director of product standards for Canada. Mr. Card will assist Westminster's management in patterning their quality standards after those of Scott Paper Co., which will acquire a half interest in Westminster by July, 1958.

Scott

J. George Breitling has been appointed assistant industrial sales manager of Scott Paper Co., Chester, Pa. Fred L. Witt has been appointed manager of industrial planning for Scott.

Consolidated

Consolidated Water Power & Paper Co., Wisconsin Rapids, Wis., will begin warehousing and selling corrugated boxes, cartons, and tubes at Albert Lea, Minn. An 18,000 sq. ft. building has been leased for future use, while operations are being started in temporary quarters.

Consolidated has requested permission to build a causeway to Hunters Island in the Wisconsin River for the purpose of building a soil filtration pond to treat spent sulphite liquor.

Stone Container

Stone Container Corp., Chicago, Ill., has agreed to purchase for cash the outstanding stock of W. C. Ritchie & Co., manufacturers of folding boxes and other paperboard packages.

American Box

American Box Co., Cleveland, Ohio, is adding corrugated container production at its main plant to supplement its wirebound, cleated panel, and nailed wood products.

IPEX

The tenth International Printing Machinery and Allied Trades Exhibition (Ipex) will be held at Olympia, London, July 5–16, 1955.

Materials Handling Show

The 1955 Materials Handling Exposition will be held at the International Amphitheatre, Chicago, Ill., May 16–20, 1955. A materials handling conference will be held concurrently with the exposition.

Gus Ostenson, production manager of Crown Zellerbach Corp., Camas, Wash.; C. D. Coffman, general superintendent of Chesapeake Paperboard Co., Baltimore, Md.; J. E. Smith, Jr., assistant sales manager of Albany Felt Co.; and panel moderator, Roy Nilsen, mill manager of Northwest Paper Co., Cloquet, Minn., as they appeared on a panel discussion of "What Is Good Felt Performance?" This presentation was the feature of the 2-day mid-winter sales meeting at Albany Felt Co., Albany, N. Y., which was attended by more than 100 of the company's sales and service engineers, research, and production personnel

Welding Show

The American Welding Society will produce its third annual Welding Show at the Municipal Auditorium, Kansas City, Mo., June 8–10, 1955.

Waste Conference

The fourth Southern Municipal and Industrial Waste Conference will be held March 31–April 1, 1955, at the College of Engineering, Duke University, Durham, N. C.

Whiting

The Whiting Corp., Harvey, Ill., has opened a new district office at 1610 Liberty Life Bldg., Charlotte, N. C. The manager of the new office is Fred W. Fisher, and Harvey K. Waters has been assigned to Mr. Fisher's staff.

T. L. Ivan has been assigned to Whiting's Ardmore, Pa., office as a sales engineer, and A. H. B. Stensland has been assigned to the Pittsburgh, Pa., office.

D. J. Murray

S. D. Payzer has been named vice-president in charge of engineering of the D. J. Murray Mfg. Co., Wausau, Wis.

Buckman

U. S. Patent No. 2,686,119 has been granted to Stanley J. Buckman and Robert N. Meals and assigned to Buckman Laboratories, Memphis, Tenn. The patent covers a method of controlling slime and deterioration of aqueous paper stock by adding one of several organic mercury compounds and alkali metal salts of 2,4,6-trichlorophenol.

Witco

An extended business trip through the Far East is to be undertaken this year by Leslie D. Carver, export technical sales manager of Witco Chemical Co., and Continental Carbon Co., New York, N. Y.

G.E.

General Electric Co., Schenectady 5, N. Y., has published a revised bulletin (GEA-5516B) describing its combustion gas turbines for power generation and mechanical drive.

Graver

Graver Water Conditioning Co., New York, N. Y., has opened a new Texas District office at 5343 McCormick St., Houston, Tex., under James J. Hanratty, manager.

Stocker

Ken Hendrick, who has operated the Chicago office of Stocker Mfg. Co. for the past several years, has opened a Stocker office at 6815 W. 77th St., Overland Park, Kan.

Research-Cottrell

Research-Cottrell, Inc., Bound Brook, N. J., has published a bulletin describing its electrical precipitation equipment and discussing the principles and applications of electrical precipitation.

Torrington

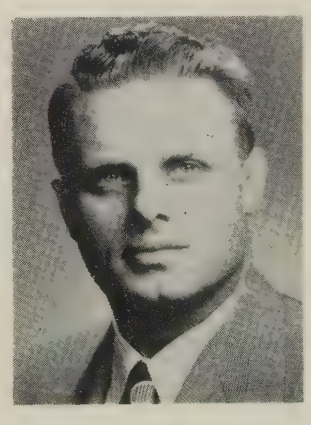
The Torrington Co., Torrington, Conn., is investigating the possibilities for diversifying its operations further. Torrington operates 10 plants in the U. S., Canada, England, and Germany.

Nopco

Travis V. Rankin has been appointed general sales manager of the Pacific Division of Nopco Chemical Co., Harrison, N. J., replacing Harold A. Swanson who has become assistant vice-president in charge of the Vitamin Division. Walter E. Brewer replaces Mr. Rankin as Central District sales manager and also continues as Eastern Industrial Sales District manager.

W. B. Morehouse (right), assistant vice-president of the Nopco Chemical Co., discussing plans with R. B. Porter (left), new technical service representative for Nopco's Chemicals Division

R. B. Porter has been appointed technical service representative for Nopco's Paper Chemicals Division.



T. V. Rankin, Nopco Chemical Co.

W. E. Brewer, Nopco Chemical Co.

MONSANTO

Monsanto Chemical Co. has opened a new paper chemicals laboratory at St. Louis, Mo., under its Organic Chemicals Division. The new laboratory, which is part of the division's research expansion program now under way, will concern itself primarily with the fortified rosin sizes which Monsanto markets under the trade name Mersize.

B & W

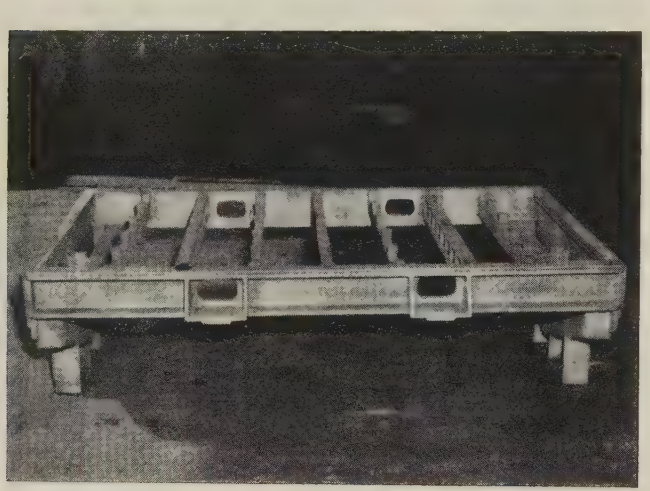
The Babcock & Wilcox Co., New York, N. Y., has purchased the assets and business of Globe Steel Tubes Co., Milwaukee, Wis. The Globe plant will become part of the company's Tubular Products Division, which has headquarters at Beaver Falls, Pa., under Edward A. Livingston, vice-president. G. H. Rearick has been named manager of the Milwaukee plant, and W. C. Buchanan, formerly president of Globe, has been elected vice-president-consultant of B & W.

Dow

The Dow Chemical Co. has issued a revised catalog, *Products of the Dow Chemical Company,* available from Technical Service and Development, The Dow Chemical Co., Midland, Mich.

Esco

The Electric Steel Foundry Co., Portland, Ore., is using the cast weldment process to produce specialized units of various types, including frames for Ahlfors Upflow Vibratory Pulp



Ahlfors screen frame which was constructed by welding at the Electric Steel Foundry Co.

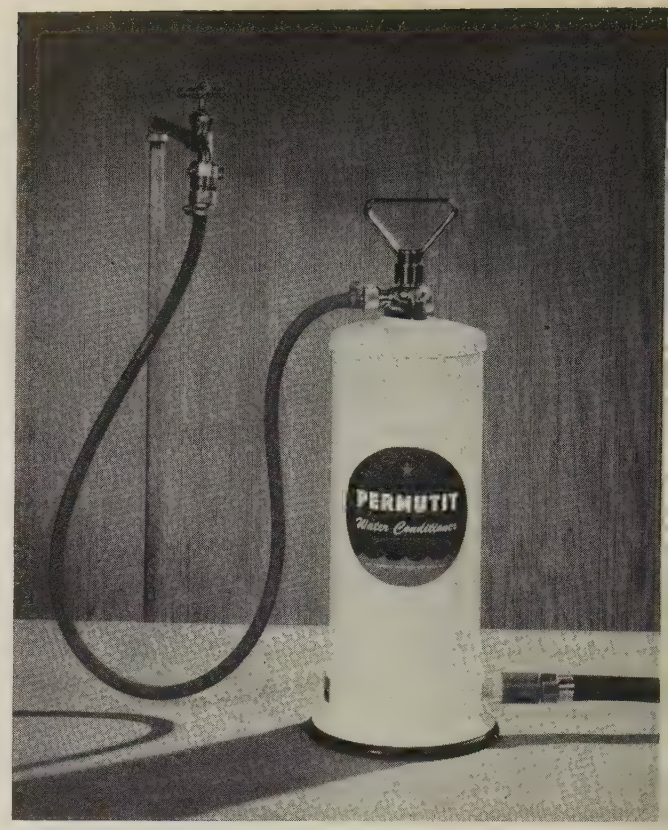
Screens. Instead of the bolted construction formerly used, the unit is divided into castable segments which are welded together. The Ahlfors screen is produced by Oliver-United Filters, Inc.

HOOKER

Hooker Electrochemical Co., Niagara Falls, N. Y., has added extra features to its new plant which began production of chlorine, caustic soda, and hydrogen at Montague, Mich., early in 1954. Evaporation equipment was added to produce 73% caustic in addition to the 50% caustic planned originally. Docking facilities were installed on White Lake and a $1^1/_2$ million gallon caustic storage tank was erected. More land was bought for future expansion, and the boiler house chimney design was changed to permit a height of 225 feet. Facilities were also added for maximum protection against air and water pollution.

CARBORUNDUM

The Carborundum Co., Niagara Falls, N. Y., has completed two new warehouse and office buildings in California and has reorganized sales, engineering, and other services in the West into a Pacific Division under John G. Fritzinger.



Permutit portable demineralizer, model MBD-6A

PERMUTIT

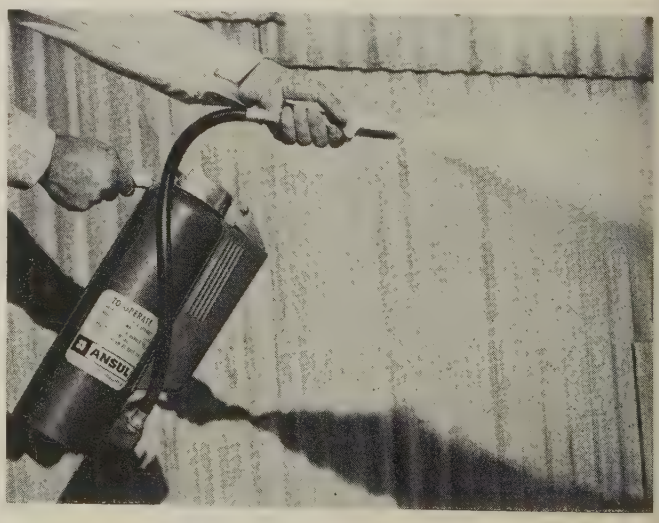
The Permutit Co., New York, N. Y., has developed a small portable dimineralizer, model MBD-6A, for the production of 1 to 2 g.p.m. of pure water. The device contains a bed consisting of a mixture of a cation exchanger and a highly basic anion exchanger.

BRANSON

Branson Instruments, Inc., Stamford, Conn., has issued a new catalog giving complete information on Audigage ultrasonic thickness gages.

ANSUL

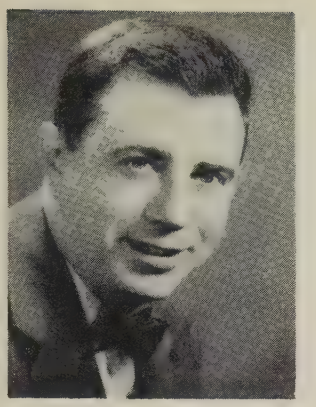
Ansul Chemical Co., Marinette, Wis., has introduced a new streamlined fire extinguisher, said to be the most rugged, effective, and easy-to-use unit ever put out in the fire protection field.



New Ansul fire extinguisher

Minerals and Chemicals

Robert W. Wilkerson has been appointed advertising and sales promotion manager of Minerals and Chemicals Corp. of America, with headquarters in Metuchen, N. J.



R. W. Wilkerson, Minerals & Chemicals Corp.

Reichhold

Reichhold Chemicals, Inc. now occupies the entire 65,000 sq. ft. building at 525 North Broadway, White Plains, N. Y.

Fiberglas

Owens-Corning Fiberglas Corp., Toledo, Ohio, has issued a booklet (GL6.C4) describing the various types of Fiberglas Aerocon insulation.

Koppers

Koppers Co., Inc., has purchased the F. X. Hooper Co., Glen Arm, Md., and will operate it as a subsidiary, under the Metal Products Division. The plant will be under the direction of three of its present officers, E. A. Metz, president, E. L. Mumma, vice-president and general manager, and J. D. O'Neill, vice-president and comptroller.

J. O. Ross

Charles R. Herter has been made district manager in charge of the Detroit, Mich., office of J. O. Ross Engineering Corp.

E. D. Jones

E. D. Jones & Sons Co., Pittsfield, Mass., has issued four new bulletins: EDJ-1061 featuring the latest model Liebeck disintegrator, EDJ-1035A covering the Jones Fibremaster, EDJ-1022A giving maintenance and parts data for Jones Jordans, and EDJ-1062 giving maintenance and parts data for Jones Fibremasters, Stockmasters, and midget jordans.

Asten-Hill

Asten-Hill Mfg. Co. has started construction of a plant at Walterboro, S. C., designed for the manufacture of asbestos drier felts, like the company's main plant at Philadelphia, Pa.

Carpenter

The Alloy Tube Division of the Carpenter Steel Co., Union, N. J., has issued a new catalog on fabricating and working stainless steel pipe and tubing. A second new Carpenter catalog deals with the control of corrosion in stainless tubing and pipe.

International Nickel

The International Nickel Co., 67 Wall St., New York, N. Y., has published a basic reference bulletin (A-69) titled "Guide to the Selection of Engineering Irons."

Westinghouse

Westinghouse Electric Corp., P. O. Box 2099, Pittsburgh 30, Pa., has issued a catalog (B-6505) covering its motion pictures and slide films.

National Starch

Negotiations for the merger of the Corn Processing Division of Clinton Foods, Inc., with National Starch Products have been discontinued.

Appleton Wire

Appleton Wire Works, Appleton, Wis., has purchased a controlling interest in the International Wire Works, Menasha, Wis. International will continue to operate as a separate company.

Reliance

The 1954 annual report of Reliance Electric and Engineering Co., Cleveland, Ohio, devotes several pages to the new special types of motors being developed by the company, the Reliance Variable Speed drive, and the special electronic devices used by Reliance in its new developments in the field of automation.

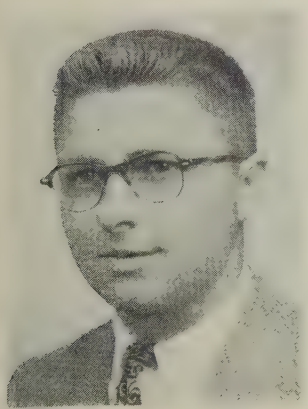
Black-Clawson

Black-Clawson International, Ltd., London, and the Rotareaed Corp., Bronxville, N. Y., have completed arrangements whereby the Deculator process will be manufactured and sold by B-C International.

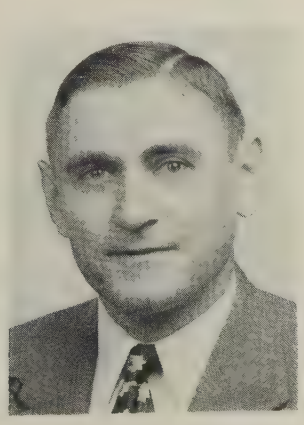
The Bagley-Sewall Corp., division of Black-Clawson, has terminated agreements with the Dan Charles Agency of Seattle, and placed full representation of the company on the west coast under Gordon Petrie, B-C's west coast sales manager.

James H. Martindale has been appointed chief engineer of B-C's Shartle Bros. Machine Division at Middletown, Ohio. Frank C. Duvall has been named first assistant chief engineer, John H. Pearson becomes assistant chief engineer in charge of new equipment design and electrical control systems, and Earl R. Zuehlke is appointed assistant chief engineer in charge of hydraulic design and application.

B-C has formed a new Research and Development Department under Joe Baxter, Jr., director of research and development.

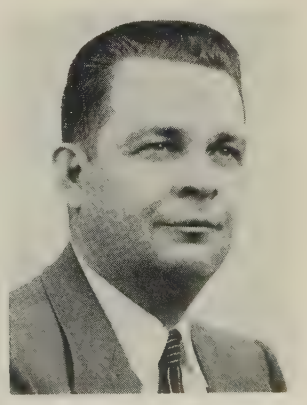


J. H. Martindale, The Black-Clawson Co.

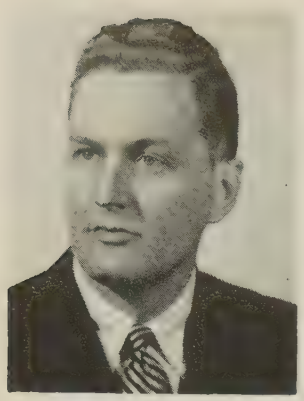


F. C. Duvall, The Black-Clawson Co.

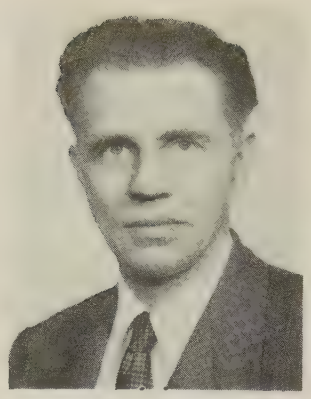
E. R. Zuehlke, The Black-Clawson Co.



Joe Baxter, Jr., The Black-Clawson Co.



W. N. Stickel, Texon, Inc.



Nils Klykken, Kamyr, Inc.

Harry Glenn, Kamyr, Inc.

G. L. M. Hellstrom, Kamyr, Inc.

TEXON

Wesley N. Stickel has been elected a director of Texon, Inc., South Hadley Falls, Mass. Mr. Stickel was also elected vice-president in charge of research, and George D. Wood was elected vice-president in charge of production.

KAMYR

G. L. M. Hellstrom, president of Paper Machinery, Ltd., Montreal, Canada, has been elected honorary vice-president of Kamyr, Inc., Hudson Falls, N. Y., in recognition of his great service in introducing and developing the Kamyr equipment in the U.S.A. and Canada. Harry Glenn, also of Paper Machinery, has been elected a director of Kamyr, and Nils Klykken has been elected vice-president in charge of engineering.

HERCULES

Hercules Powder Co., Wilmington, Del., is planning expansion of its facilities for the production of wet-strength resins at its Holyoke, Mass., plant.

Hercules has consolidated its chemical cotton and its CMC-ethyl cellulose plants at Hopewell, Va., under Floyd L. Boddicker. Formerly two separate departments, the two plants will be operated by the Virginia Cellulose Departments.

The company is planning a plant near Franklin, Va., for the processing of about 35,000 tons per year of tall oil. Operation is expected to begin early in 1956.

BBD

Bensing Bros. & Deeney, Philadelphia, Pa., have appointed Joseph T. Woods manager and vice-president in charge of production of the new BBD flexographic inkmaking plant in San Leandro, Calif. Edward J. Dougherty is vice-president in charge of sales for the new operation, and Kenneth Nelson becomes sales-service representative in the southern part of the territory.

P & W

The Parsons & Whittemore-Lyddon Organization, 250 Park Ave., New York, N. Y., has issued a booklet dealing with a mechano-chemical process for pulping straw, bagasse, grasses, and other agricultural residues.

Another new P & W booklet describes the growth of the organization since its founding in 1853. All phases of the company's activities are covered, including its world-wide bartering and compensation service which facilitates international trading to circumvent exchange difficulties, and its private "Point Four" program for pulp and paper projects in Central and South America, Africa, and Asia.

SANDY HILL

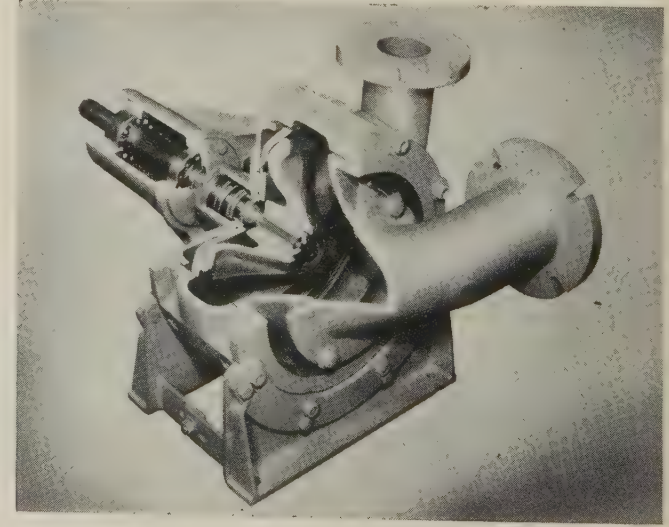
Sandy Hill Iron and Brass Works, Hudson Falls, N. Y., has supplied two "Pillo-Pak" machines to make a new molded corrugated sheet, which is exceedingly flexible, tough, and light in weight, at the Packaging Materials Corp., Astoria, L. I., N. Y. The new product owes its crush resistance to the fact that the corrugations are solid in cross section, the sheet being formed on a cylinder and dried in an air drier.

WEMCO

The Western Machinery Co., 760 Folsom St., San Francisco, Calif., has introduced a new type of pump, the Wemco Torque-Flow solids pump, which can handle a variety of solid meterials without clogging, becoming damaged, or damaging the solids being pumped. The pump impeller operates in a

Kenneth Nelson, Bensing Bros. & Deeney

E. J. Dougherty, Bensing Bros. & Deeney



Wemco torque-flow solids pump

recess at one side of the casing, creating a swirl which picks up the material from the intake and carries out the discharge, so that few of the solid particles ever touch the impeller itself. It has proved possible to pump anything from live fish to ready-mixed concrete in test installations.

INQUIRIES

When writing to companies about items that appear in the *Tappi* Industry Notes, please be sure to state that you saw the item in *Tappi*.

OBITUARIES

Frederic C. Clark

Frederic C. Clark, retired, died at Manchester, Vt., on Dec. 25, 1954.

Mr. Clark was born at Newark, Del., in 1882 and graduated as a mechanical engineer from the University of Delaware in 1903.

Following graduation he was employed as an operator (3 years) by the International Paper Co., Palmer, N. Y.; night superintendent (1 year), Burgess Sulphite Fibre Co., Berlin, N. H.; assistant superintendent (4 years), Curtis & Bro., Newark, Del.; Chief of Paper Section (8 years), National Bureau of Standards, Washington, D. C.; director of technical control (3 years), American Writing Paper Co.; general manager ($2^1/_2$ years), Pejepscot Paper Co., Brunswick, Me.; manager and secretary ($2^1/_2$ years), Hawthorne Paper Co., Kalamazoo, Mich.; part owner (3 years), East Hartford Paper Co., Burnside, Conn.; vice-president (8 years), Skinner & Sherman, Inc., Boston, Mass.

Frederic C. Clark

Since 1938 Mr. Clark engaged in private practice as a consulting engineer in the manufacture of pulp and paper with offices in Waltham, Mass., New York City, and Manchester, Vt.

Fred Clark was a charter member of the Technical Association of the Pulp and Paper Industry and served as its president in 1938 and 1939. In 1921 and 1922 he served as vice-president of the Association.

He is survived by his wife, Eleanor Williams Clark, and daughter, Mrs. Charlotte Grant. In his memory the Frederic C. Clark Memorial Fund was established at the Zion Episcopal Church, Manchester, Vt.

Gerald Gale Johnston

Gerald G. Johnston, production manager of the mill division of the Waldorf Paper Products Co., St. Paul, Minn., died suddenly of a heart attack at his home in St. Paul on Dec. 15, 1954.

Mr. Johnston was born in Dahinda, Ill., on April 9, 1913 and was graduated from the University of Illinois and received his doctor of philosophy degree from The Institute of Paper Chemistry in 1940.

Following graduation he joined the Waldorf organization where he rose to the positions of chief chemist and production manager of the mill division.

He is survived by his wife and children, Robert, Bonnie, Jean, Patricia, and Larry, his mother, and two brothers, Ernest and Ralph.

Mr. Johnston became a member of the Technical Assocation of the Pulp and Paper Industry in 1939.

Russell Starkey Bracewell

Russell S. Bracewell, vice-president of Kupfer Bros. Co., Northbridge, Mass., died on Dec. 13, 1954, at his home in Milford, Mass.

Mr. Bracewell was born in Lineville, Iowa, on July 18, 1891, and graduated as a chemist from the University of Kansas in 1916.

In 1920 he joined the research staff of the American Writing Paper Co., Holyoke, Mass., and in 1921 he became vice-president and secretary of the Marvellum Co. in Holyoke. In 1950 he became plant manager and more recently vice-president of Kupfer Bros. Co. in Northbridge.

Mr. Bracewell was a member of the Technical Association of the Pulp and Paper Industry.

Johannes Westergaard

Johannes Westergaard, president of Westergaard & Co., New York, N. Y., died of an accident on December 22.

Mr. Westergaard was born in Oslo, Norway, on Aug. 5, 1897, and attended the University of Oslo for a year. Prior to emigrating to the United States when he was 19 he was employed by Caske Cellulosefabrik. He was employed for the first five years in the United States by Pagel-Horton Co. Following this employment he joined the firm of Nelson & Lyon and later the firm of Atterbury & McKelvey. He organized the firm of Westergaard & Co. in August, 1954, following a period as an officer of Castle & Overton, Inc.

He was president of the Association of American Woodpulp Importers from 1939 to 1941 and from 1953 until his death. At the beginning of World War II he was active in the organization and was chairman of Norwegian Relief in the United States. In 1940 he was decorated by King Haakon of Norway with the Order of St. Olaf for his general contributions to Norway.

He is survived by his wife, Astrid, two daughters, Thore and Anna, and a son John, in the U. S. Armed Services.

Mr. Westergaard became a member of the Technical Association of the Pulp and Paper Industry in 1928.

Harold H. Brown

Harold H. Brown, consultant, died of a heart attack in Grand Central Station, New York, N. Y., on Dec. 30, 1954.

Mr. Brown was born in Three Mile Bay, N. Y. on March 18, 1887, and received his Ph.D. degree from the University of Minnesota in 1914. He received his A.M. degree from Syracuse University in 1910.

In 1913 he was a chemist for the Pittsburgh Plate Glass Co., Pittsburgh, Pa., and from 1914 to 1920 was a chemist for the U. S. Department of Agriculture, Washington, D. C., where he studied methods of eliminating dust explosions, especially in grain elevators. In 1920 he was chemist for the Pejepscot Paper Co., Brunswick, Me., and in 1921 became chemist for the Missisquoi Corp., Sheldon Springs, Vt. Since 1923 he has been engaged as a consultant in New York City, specializing in the problems relating to agricultural wastes.

REPORTS AND DISCUSSIONS

Presented at the National and Regional Conferences

Slagging Problems in Furnaces and Superheaters

THE following papers comprise the introductory remarks of the panel on "Slagging Problems in Furnaces and Superheaters" at the Ninth Engineering Conference, Philadelphia, Pa., Oct. 18, 1954. W. M. Wyburn, Federal Paper Board Co., Inc., chairman of the Steam and Power Committee, was moderator.

FUEL ADDITIVES—F. G. ELY (The Babcock & Wilcox Co., Alliance, Ohio)

Difficulty caused by ash and slag presents one of the most obstinate and challenging problems encountered by the designer and operator of steam generating equipment. For a given plant the selection of a satisfactory fuel may depend as much upon the nature of its ash characteristics as upon the more obvious factors of availability and price. Where natural gas is available, it is in most respects, an ideal choice, not only because of simple transport and firing control, but also because of its freedom from fouling residues. Compared to coal or other solid fuels, oil has a similar attractiveness in ease of fluid transport and firing simplicity. With ash content of only 0.2 of 1%, it has generally been regarded as a clean fuel.

Recent years have witnessed a tremendous increase in the use of oil for steam and power generation in pulp mills and other industrial or utility plants of the seaboard states. Accompanying this gain, and partly accountable for it, has been a considerable change in the logistics of supply from new and widespread sources of crude oil and in the enlargement of refining capacity.

Also apparent, however, is an unfortunate increase in the amount of difficulty caused by ash and slag in oil-fired boiler units.

One of the more obvious explanations of this is the fact that refining practices also have changed with the result that higher yields of gasoline and intermediate distillates are produced at the expense of the residual fuel. From nearly half of the input crude, obtained with straight-run distillation, the volume of residuals has been reduced to less than 20%, by vacuum distillation, thermal and catalytic cracking, and theoretically may even be carried to extinction by the more recently developed coking processes. Thus the impurities of the crude are retained in greater concentration in the diminished volume of residuals presently marketed for use as fuel oil. But even if doubled, the ash content is still relatively low, and one must look to the nature of the ash constituents for a key to slagging problems.

Complete analyses of oil ash have disclosed the possible existence of virtually all known metal ions among crudes from various producing fields. To some extent these impurities are characteristic of the locality or field. Other impurities may be contributed by contamination in transport (for example, sea water, tank or pipe-line rust, etc.), or from refining methods. Probably the most significant, from the standpoint of tube slagging, are the compounds of the alkalies, vanadium, and sulphur.

In the combustion chamber, reaction products from sodium and potassium, with oxygen and sulphur, produce a low-fusing sulphate ash which can readily adhere to tube surfaces in the critical region of the superheater. Accumulation of deposits not only retards heat transfer, but may cause bridging of the gas-flow spaces between tube rows, and because of the compact and sticky properties of the ash at operating temperature, may resist the action of sootblowers or other cleaning methods.

This condition can be counteracted in new design by providing wider spacing of superheater tubes, and the use of vertical elements which are less susceptible to bridging. Units of such design can be kept in service for acceptable periods with normal sootblower operation. The problem remains, however, of alleviating troublesome conditions on older installations or of meeting unexpected changes with fuel from different sources.

Considered from the standpoint of ash composition, it becomes at once a natural conclusion that treatment of the fuel to alter its ash characteristics in a favorable direction would provide the best means for overcoming slagging difficulties. In the oil as fired, the objectionable constituents are present in such small amounts and in such chemical combinations that methods for their removal are difficult or impossible to apply economically on a commercial scale. For the same reason, however, the addition of corrective constituents, which might alter the fusing properties of the aggregate ash, offers an attractive possibility.

Studies of this subject were undertaken some years ago by the Babcock & Wilcox Co. in laboratory and pilot scale equipment, and it was found that a number of low-priced materials, such as finely divided oxides of aluminum, calcium, and magnesium, produced desirable effects of raising the fusing temperature of the mixture, or producing an ash of more granular and friable texture at the temperatures encountered in a superheater pass. The results of these studies and subsequent full-scale application to an operating unit at the Inglis Station of Florida Power Co., are fully described in a paper by McIlroy, Holler, and Lee.

At this plant, a small tank was installed, in which an 8-hr. batch of fuel oil and additive slurry could be prepared, which was then delivered by a proportioning pump to a mixing tee in the main oil line supplying the burners. Alumina additive at a rate equal to a 1:1 ratio of fuel ash was thus supplied to the furnace at the zone of atomization with good dispersion throughout the products of combustion. In a 4-month trial of this material, it became apparent that desirable effects were being obtained, and that while the amount of ash deposited on the tubes was greater than without the use of additive, its texture was such that it could readily be removed within the range of conventional sootblowers or air lances which had been ineffective on the original slag.

Following the trial of alumina, a locally procurable dolomite product was used in the same manner, and evidenced an even greater effectiveness in producing a fluffy deposit. Use of dolomite at the low cost of 1 cent per lb. (equivalent to $^1/_2$ cent per barrel of oil) has been continued at Inglis Station with realization of savings in greater boiler availability and efficiency, and the maintenance of an operably clean unit with no outages required because of slag accumulation.

Concurrently with the trial of additive for slag control, attention was given to its effect on corrosion conditions in the low-temperature end of the unit. Technical studies indicated a reduction of sulphur trioxide content of the flue gases, a lowering of the dewpoint temperature, and alkaline reaction of the dust carried in the gas stream. Operating experience has subsequently demonstrated a pronounced reduction of

air heater corrosion and plugging of tubes, and in addition a virtual elimination of complaints arising because of corrosive effects of material discharged from the stack on neighboring structures and equipment.

While this subject of the use of additives is a comparatively new development, it has elicited wide interest among users of residual fuel oil, and a number of applications of additive treatment have been made at several plants for similar purposes. In one installation, subject to vanadium attack of high-metal-temperature tube surface, additives were found to be beneficial but not completely corrective of such high temperature corrosion. Use was continued, however, by air-borne introduction of material ahead of the regenerative-type air heater for improvement of low-temperature corrosion and fouling conditions.

In the mechanism of slagging and corrosion it is believed that sulphur in the fuel, burning to sulphur dioxide, is oxidized to sulphur trioxide in proportions dependent on temperature, equilibrium, and reaction rates, and catalytic effects of exposed surfaces or of ash particles carried in the gas stream. Reaction of sodium and potassium compounds with sulphur trioxide produces an easily fused alkali sulphate (melting temperature as low as 1600°F.) which supplies the principal slagging component. The presence of calcium and magnesium oxides, resulting from the calcination of dolomite in the high-temperature zone of the furnace, causes a formation of calcium or magnesium sulphate, having higher fusing temperature, which chemically or mechanically alters the structure of the deposited slag and renders it more easily removable. In the cooler passes of the superheater and boiler, more favorable to sulphur trioxide concentration, reduced formation of sulphuric acid, the most prominent corrosive agent in economizer or air heater sections, and corresponding lowering of the acid dewpoint at metal surfaces which are cooled by inlet air or feedwater.

Although other additive compounds, such as magnesium oxide, have also been found effective in field trials, it is believed that dolomite, because of its relativelp low cost, offers greater economic advantage.

In addition to the improvement of boiler availability and maintenance cost, it is possible that additives may permit the use of lower-quality fuels purchased at substantially lower prices because of their objectionable ash characteristics.

LITERATURE REFERENCES

McIlroy, J. B., Holler, E. J., and Lee, R. B., "The Application of Additives to Fuel Oil and Their Use in Steam-Generating Units," ASME paper 52-A-160.

Huge, E. C., and Piotter, E. C., "The Use of Additives for the Prevention of Low-Temperature Corrosion in Oil-Fired Steam Generating Units," ASME paper 53-A-235.

Campbell, O. F., "Additives in Residual Fuels Reduce Ash Deposits on Steam Boiler Parts," *Oil & Gas J.* (March 22, 1954).

SLAGGING PROBLEMS IN COAL-FIRED BOILERS—RUSSELL V. KNAPP (Mosinee Paper Mills Co., Mosinee, Wis.)

In considering slagging in coal-fired boilers, the operator has two very definite problems: first, he must endeavor to prevent slagging, and second, if slagging does occur, he must get the slag off or pay the penalty of an appreciable drop in boiler efficiency.

While our subject states the problem is "slagging," I believe we are all in general agreement that all external fouling of boiler heating surfaces is the problem to be considered.

It is well known that boiler design, furnace volume and design, type of firing equipment, character of coal, percentage of excess air, and rate of firing all have an effect on heating surface fouling.

Boiler design refers to arrangement of heating surfaces, slag screens and baffles, and location of superheater as well as tube size, spacing, etc.

Furnace volume and rate of firing determine heat release values, and furnace design refers to arrangement of the furnace and the amount of water cooling, all of which tend to determine maximum furnace temperatures except as modified by per cent excess air used for combustion.

Type of firing equipment refers to underfeed stokers, traveling grate stokers, spreader stokers, pulverized coal, or the cyclone furnace.

Character of coal refers to ash fusion temperature, ash volume, and coal sizing.

It is the function of the boiler manufacturer to arrange heating surfaces, determine furnace volume and design, locate superheater, and position baffles in such a manner that a minimum of fouling will occur for the type of firing equipment and coal specified by the operator. It is then the job of the operator to control the variables affecting fouling so as to keep it at an economical minimum, and after fouling has occurred, remove the fouling material.

Obviously, a pulverized coal-fired unit will, in general, be afflicted with more fouling than an underfeed, traveling grate, or spreader stoker, when burning a given coal at a given rate of steaming since the maximum amount of ash will be carried into the boiler passes in such a unit, as a result of coal size.

More ash is carried over in a spreader stoker installation than in the other types of stokers, but enough of the ash is of such size that a scouring action is obtained which tends to keep the heating surfaces clean. With proper design such a unit can be operated without any tube cleaning equipment.

The underfeed and traveling grate stokers are "middle of the road" equipment, and with the given type of coal, the amount of fouling will depend largely on coal sizing which will determine the amount of ash carried into the heating surfaces.

In all cases, the volume of ash carried over will obviously be determined by the rate of burning and, as the rate of burning increases, the amount of ash carried over and the furnace temperature will increase. As the furnace temperature increases, the ash approaches or exceeds its softening or fluid temperature so that more of it will tend to adhere to the heating surfaces, and, depending on boiler design, enough ash may be deposited to cause bridging between tubes.

Other factors affect fouling, such as dewpoint of flue gases, per cent of sulphur in the coal, and all could be more thoroughly discussed, but time does not permit. It is apparent, however, that the operator must burn a coal having a suitable ash fusion temperature and size for his particular job in order to keep the fouling of his boiler units within desired limits.

It may not be economical to burn coal having the highest fusion temperature, since the cost of that coal might be so high that additional boiler cleaning costs could be justified when burning a cheaper coal with a lower fusion temperature.

Excess air for combustion should be closely controlled as per cent of excess air has a definite effect on furnace and flue gas temperatures and, in some cases, an effect on ash fusion temperature. In general, the fusion temperature of ash will be lower in a reducing atmosphere than in an oxidizing atmosphere. In a stoker-fired installation where a fuel bed exists, there undoubtedly is a zone where a reducing atmosphere can exist if excess air value is improperly maintained.

Other means of diminishing fouling are control of humidity of the combustion air supply and the use of fuel additives. As an operator, I have been somewhat antagonistic toward the use of additives as some of them have the faint tinge of racketeering, even though some additive materials are undoubtedly very effective.

The second problem of the operator, that of removing the fouling material from the boiler heating surfaces, is a tough one, for two reasons: first, the method of removal to be

employed must be decided upon, and second, how dirty should the heating surfaces be before it will pay to remove the deposits.

The fouling depositions may be removed in a number of ways; such as scraping, sand or ash blasting, washing, or chemical spraying. There may be other ways or means of removing the deposited material, but those mentioned are all that have come to my attention.

Scraping and blasting are more or less self-explanatory means of cleaning, but the other two methods are deserving of some comment.

Washing may be done in a number of ways, but it is felt that use of high pressure water is preferable, for the higher the pressure, the smaller the amount of water used which will minimize the possible damage to any refractory material in the setting. Some hydroxide may be used to increase the pH of the wash water if desired, particularly if the ash contains any appreciable amount of sulphur compounds.

Chemical spraying is being used in some cases where a solution is atomized and drawn into the setting by the air flow through the setting until the tube surfaces are completely wetted. The boiler is then fired and the fouling material presumably drops off. The idea is that the chemical will be such that it penetrates the deposition and will vaporize when heated so that it will crack the scale loose. The character of solution used will depend on the composition of the material to be removed.

There are undoubtedly a number of things involved in boiler fouling problems which I have overlooked, but I feel I have touched on the main points and hope that some of you may have found a little assistance somewhere in this very brief discussion.

Note: Since the October meeting in Philadelphia, chemical cleaning of one boiler in the author's plant was carried out and while some scale was not removed a drop in economizer outlet flue gas temperature of over 50°F. was obtained.

FUEL OIL BURNING AND SLAGGING—N. H. MAILHOS (Brunswick Pulp & Paper Co., Brunswick, Ga.)

For the successful burning of fuel oil in industrial boilers there are certain factors that must be given careful consideration. Let us list those factors and discuss each in order: (1) fuel oil analysis, (2) fuel oil pumping facilities, (3) proper oil strainers, (4) fuel oil heating facilities, (5) proper type burners, (6) sufficient air, (7) adequate furnace volume, (8) adequate heating surface, (9) proper soot blower equipment, and (10) proper operation.

Fuel. Fuel oil used for steam generation in power plant boilers is the residue from the refining of crude oil. In the refining process the lighter oils, such as gasoline, kerosene, diesel oil, and gas oil which are vaporized at comparatively low temperatures, are removed. Because of the absence of the light oils, the use of fuel oil is safer from fire hazards than crude. It is also cheaper than the crude oil because the lighter oils can be sold at higher prices.

The chief advantages of fuel oil as compared with coal in the generation of steam are that it can be easily moved from storage to the place of use, the burning equipment is simple and fairly easy to operate, and very little ash is present to clog the gas passes of the steam generating unit. The composition and heating value of fuel oil are more nearly constant as compared with these same properties of coal.

The important properties of fuel oil are: (1) specific gravity, (2) heating value, (3) viscosity, (4) flash point, (5) fire-point, (6) sulphur content, and (7) ash content.

Density is an important property of fuel oil, since it is sold on a volumetric basis. Standard density is taken at 60°F. and referred to water at 60°F. A barrel of 42 gal. has an average weight of 336 lb. The density is usually designated in degrees API, for which the American Petroleum Institute's standard formula is:

$$\text{Degrees API} = \frac{141.5}{\text{specific gravity} \times 60°\text{F.}/60°\text{F.}} - 131.5$$

Between the specific gravity of all petroleum products and their higher heating value there is a relationship which has been expressed in a formula by the U. S. Bureau of Standards as:

$$22{,}320 - 3780 \times \text{specific gravity (at } 60°\text{F.}/60°\text{F.)}$$

A typical fuel oil analysis is as follows:

Carbon	86.50%
Hydrogen	11.00%
Nitrogen	0.29%
Sulphur	0.94%
Oxygen	1.02%
Moisture	0.20%
Ash	0.05%

The oil normally has a gross heating value of 18,600 B.t.u. per lb. and a flash point of 198°F. The specific gravity being 17.9° Bé. However, as you know the composition and heating value of fuel oil are not constant, therefore a continuous check should be made on your fuel oil supply.

Sulphur is a very undesirable element in fuel oil, because its products of combustion are acids which causes corrosion in economizer, air heater, and gas ducts. Coupled with the high hydrogen content in the oil, and the resulting high water vapor content in the products of combustion, sulphur in fuel oil does more damage than the same amount of sulphur in coal.

Fuel oil also contains all of the solid impurities originally present in the crude oil. Should these solids contain a large proportion of salt, they are very fusible and will stick to the boiler and superheater tubes and cause considerable trouble. Vanadium is also found in some oils, principally South American oils, and when present will also cause trouble.

When pumping oil from storage tanks to heaters a viscosity of 700 sec. Saybolt furol is required and is obtained by heating the oil to a temperature of 100°F.

For steam atomizing burners a viscosity of 40 sec. Saybolt furol is required and is obtained by heating the oil to a temperature of 185°F. The oil pressure required for steam atomizing burners ranges from 2 to 125 p.s.i.g. Pressure should be kept as low as possible and still furnish the quantity of oil required to carry the boiler load.

For mechanical atomization the oil requires greater fluidity and therefore, must be heated to 220°F. Mechanical atomization requires a pressure range of 50 to 250 p.s.i.g.

Fuel oil should never be heated to 250°F. or above as the solids begin to drop out at that temperature and nothing is to be gained.

Pumping Facilities. From the above you can see that pumping requirements will depend on the type of burner as far as pressure is concerned, and, of course, on individual plant requirements as far as capacity is concerned. Excess capacity should be provided in order to meet emergencies and unusual demands. In the selection of pumps, consideration should be given service and maintenance based on past performance.

Oil Strainers. Strainers should be considerably oversized and preferably the dual type so that oil to the burners can be strained at all times. This will prevent tip from clogging with resultant burner outage. These strainers should be cleaned systematically.

A fuel oil additive (there are several on the market) should be added to the fuel oil, in storage tank, in sufficient quantity to keep all sludge in suspension and any water emulsified.

Oil Heaters. The selection of the oil heater will depend entirely on the oil temperature required and the quantity demand of the plant. Temperature requirements are governed

by the type of burners in use. Steam atomization requires a much lower temperature and pressure than mechanical atomization. Here again excess capacity should be provided in your oil heaters as provided for in your pumps.

If excess capacity is not provided, you may reach a point where control is impossible.

Proper Type Burners. In order to burn this oil fuel we must have a suitable burner. There are basically three types of industrial burners: (1) air atomizing burners, (2) steam atomizing burners, and (3) mechanical atomizing burners.

Each of the burner types requires for the oil gun a nozzle that will produce a mistlike spray of liquid fuel. The design of this nozzle is of primary importance, and is governed by the means used to produce atomization. The performance obtainable is greatly influenced by the way in which air is supplied to the atomized fuel in order to get thorough mixing. The essential elements of design for any oil burner may be summarized as follows: (1) complete atomization of the oil without drooling, clogging, or fouling; (2) maintenance of atomization over a wide capacity range; (3) correct shape of discharge throat, so as to secure mixture of atomized oil with incoming air at all points, thus assuring complete combustion with a minimum of excess air at various rates; (4) ready accessibility for effecting repairs, thereby minimizing burner outage as well as maintenance cost.

The use of burners in which air is used as the medium for effecting atomization is limited to a very few industrial installations. The reason being the relatively high cost of supplying compressed air, which is not offset by a lowered loss of sensible heat as compared with that resulting from the use of steam for atomization, or as compared with the power charge for mechanical atomization. Therefore, we will only consider the steam and mechanical atomizing types of burners.

Following is a list of the relative merits of the steam and mechanical atomizing burners. The steam atomizing burner can be subdivided into two general groups: the outside mix and the inside mix. There are three different designs for the outside mix and two for the inside mix.

The mechanical atomizing burner consists of four principal elements: (1) the atomizer for producing a fine, uniform, mistlike spray of oil; (2) the diffuser, which protects the base of the oil spray from high-velocity air, yet provides sufficient air at this point to accelerate ignition; (3) the air register which gives direction and control to flow of combustion air to the oil spray; and (4) the shaped refractory burner throat opening, whose function is to assist in mixing the air and fuel.

Steam Atomization Burner

1. Best suited to variable load.
2. Wide capacity range without changing tip or gun assembly.
3. Frequent cleaning of tip unnecessary, as openings are relatively large and can be quickly blown out with steam.
4. Capacity up to 120,000,000 B.t.u. per nozzle per hr.
5. Considerable flexibility as to shaping flame to conform with furnace conditions.
6. Relatively low oil temperature required (approximately 185°F.) as viscosity need only be low enough (40 SS F) to readily permit pumping.
7. Oil pressure 2 to 125 p.s.i.
8. Steam for atomization may vary from 0.7 to 5.0%. The approximate average for careful operation is 1.25%.
9. Steam for atomization is lost up the stack, and must be considered when there is a question of makeup water.
10. Lower air pressure required because aspirating effect of the steam jets makes up for some of the pressure drop in the register.
11. Lower fixed charges because of lower temperature and furnace requirements.

Mechanical Atomization Burner

1. Best suited to steady load and high capacity.
2. Limited capacity range for any given tip size. Wide range system overcomes this somewhat.
3. Frequent cleaning of tip necessary to maintain efficient spray. Owing to relatively small opening, entire gun assembly must be removed so sprayer plate and tip orifices may be carefully cleaned.
4. Capacity up to 100,000,000 B.t.u. per nozzle per hr.
5. No flexibility as to flame shape.
6. Relatively high oil temperature required (approximately 220°F.) as viscosity must be low enough (180 to 220 SSU) to produce satisfactory atomization.
7. Oil pressure 50 to 250 p.s.i.
8. Steam pressure for pumping and heating varies from 0.5 to 1.0%, and is governed by the equipment installed rather than by operation.
9. Exhaust steam from pump and heater set may be returned to hotwell, thereby minimizing makeup. (This is questionable.)
10. Higher air pressure required, because of the absence of aspirating effect with the mechanically produced spray.
11. Fixed charges high, owing to cost of equipment to provide for high pressure and high temperature requirements.

From the foregoing the proper type burner can readily be determined. However, it is well to remember that results obtainable depend more on furnace design than on the burner. For best results though the two should be properly coordinated.

Sufficient Air. Both induced and forced draft fans, where required, should exceed net requirements at top rating of the boiler per hour by 15% for volume and 30% for pressure. This will assure adequate control at all times.

Adequate Furnace Volume. Furnace design is affected by the economic factors of cost, duration, or hours of operation, cost of fuel, duration of peak load, and duration of minimum load, by combustion factors of efficiency, kind and character of fuel, method of firing, magnitude of peak and minimum loads, and by physical factors of space available, and type of boiler. The economic end sought is minimum cost consistent with operating conditions and with life of furnace and cost maintenance.

The furnace should be capable of sustaining the maximum continuous combustion rate with the desired excess air without slagging the furnace walls, bottom or boiler tubes. The furnace design should be such that the ash particles entering between the boiler tubes are not above their fusion temperature.

The exit furnace temperature should be held to 2000 to 2200°F. if you are to stay out of trouble from slagging. Exit furnace temperature does not depend entirely upon heat release per cubic foot of furnace, however it is common practice to limit the heat released per cubic foot of furnace volume to approximate values depending on firing method, type of furnace, and kind of fuel. Heat release per square foot of cold surface exposed to the furnace is a ratio used in determining furnace exit temperature. Keep in mind that when the exit furnace temperature reaches or exceeds the fusion temperature of the ash content of the fuel you can expect trouble from slagging of the tubes and setting.

Adequate Heating Surface. In computing the heating surface of boilers, only the surface exposed to the fire on one side and water on the other side should be considered. The ASME advocates using the inside diameters of fire tubes and the outside diameters of water tubes as basis of computation for boiler tube heating surfaces. Heating surfaces in water walls and in superheaters are usually given separately from the heating surface in the main part of the boiler.

Modern practice is to state the maximum quantity of steam in pounds per hour that the boiler is designed to generate together with the square feet of heating surface. The trend in modern design is a reduction in total heating surface and operating at from 200 to 600% of rating. This affects furnace design and furnace exit gas temperatures with resulting troubles from slagging and unavoidable boiler outages for cleaning.

Proper Soot Blower Equipment. During operation of the boiler there is some accumulation on the tubes. Therefore, soot blowing equipment should be provided in strategic sections to remove this accumulation and keep the heat transfer rate at maximum.

The retractable type of soot blower is preferable, as it removes the element from the hot gases when soot is not being blown, if practical.

Proper Operation. Assuming you have a boiler of proper design, then the unit must be operated properly if you are to stay out of trouble.

First, the oil must be kept at the right temperature and pressure. This, of course, depends on the type of burner in use. It must be kept clean by properly straining. The process of combustion in a boiler furnace is very complicated. But, regardless of what chemical reactions occur, the combustion should, in general, be complete to insure maximum economy. The products of complete combustion are (1) carbon dioxide gas (CO_2), (2) water (H_2O), (3) nitrogen gas (N_2), (4) a small quantity of sulphurous acid gas (SO_2). If combustion is incomplete, the products may contain some carbon monoxide gas (CO). There will then be a correspondingly smaller quantity of carbon dioxide. Hence the completeness of combustion may be gaged quite accurately from the amounts of carbon monoxide and carbon dioxide in the discharge gases. Usually, 10 to 15%, by volume, of carbon dioxide indicates efficient combustion.

The requisites for proper combustion are as follows:

1. The admission of an air supply such as will assure sufficient oxygen for complete combustion.

2. Since complete combustion is not, of necessity, efficient combustion, it must be secured without permitting dilution of the products of combustion with excess air. It follows then, that:

3. The air supply should be admitted at the proper time and in such manner that the oxygen of the air will come into free and intimate contact with the combustible substances in the fuel.

4. The gases must be maintained at a temperature at or above their ignition point until combustion is complete. Theoretically, the most efficient combustion is that resulting in the maximum temperature possible. In practice there are frequently factors, which from the standpoint of commercial operating efficiency, make it advisable to keep furnace temperatures somewhat below those which could be obtained were this the sole factor involved.

5. An additional requirement, which has to do with the physical rather than the chemical aspect of combustion, is that proper provision must be made for the expansion of the gases during the period of their combustion.

In closing, I would like to state that the problem of slagging in new boilers, is brought about by furnace exit gas temperatures in excess of the fusion temperature of the ash content of the fuel. This is brought about by inadequate boiler heating surface which governs the type and size of furnace, resulting in insufficient furnace volume. This is not entirely the fault of the manufacturer but is partly due to improper specifications being prepared by the purchaser. Too often you see specifications reading thusly: 100,000 lb. of steam per hr., at a design pressure of 475 lb. and a stream temperature of 750°-F. The manufacturer's bidding on such specifications must give you the least he can in a boiler to meet those meager specifications and remain competitive.

In the case of older units in service this slagging condition is brought about by an inadequacy of some of the factors mentioned previously, or an up-rating of the unit. This up-rating possibly results in furnace exit gas temperatures in excess of fusion temperature of the ash content of the fuel brought about by insufficient boiler heating surface and furnace volume at the new rating. In this case, where you have to live with this condition, there are several fuel additives on the market that will alleviate this slagging condition if not remove it entirely. Careful consideration should be given the selection of this additive for some are very abrasive and will give you considerable burner troubles.

Wherever possible, the cause should be determined and eliminated for corrective measures though not too costly singularly can be cumulative and build up too high a cost.

Operating Suggestion for Control of Slag Deposit in Boilers—J. J. Raguson (Combustion Engineering, Inc., New York, N. Y.)

Boiler design is dictated primarily by economic considerations. If no restrictions are placed on the designer, units can be designed so as to practically eliminate the troublesome factor of coal ash slag. Slag results when temperatures beyond the ash-fusion point are exceeded in the combustion chamber, causing it to adhere at vulnerable zones to refractory and heating surfaces. These vulnerable areas can be lessened by: increasing furnace size; addition of water-wall surfaces; opening up gas lanes in the boiler and superheater; elimination of refractory surfaces. These are the problems for the designer.

Of most concern here is, obviously, the continuous in-service operation of pulverized-coal-fired equipment with minimum personnel in existing plants. We should, therefore, consider how some of the factors contributing to slagging can be lessened or eliminated, and also what can best be done to alleviate any difficulty resulting from slag. Most of these require some concentrated study and observation, sometimes over a long period. A daily log will prove most helpful in making this study. Once having established the most troublesome items contributing to slag, the necessary precautions should be taken to lessen or remove it.

Today, it is pretty much a question of burning those coals which are most readily available. Frequently very little choice is given to the selection. It is advisable, therefore, to become familiar with all characteristics of the coals you are burning. In the selection of coals, consideration should be given to those whose ash-fusion temperature will fit in best with your present boilers. The usefulness of the determination of softening and fluid temperature of the ash is recognized and should be included with all coal analysis. Included also should be the iron and sulphur content of the ash because high iron content is always associated with slugging difficulties. Sulphur generally combined with alkaline metals in the ash resulting in a low fusion temperature, therefore, coals high in sulphur may also cause slag complications.

Many plants are required to burn several grades of coal with varying ash-fusion temperatures. These coals are frequently mixed in varying proportions before going to the furnace. A tabulation should be made of these mixtures and their various burning characteristics studied. While any of the several coals can be burned successfully alone, it often happens that difficulty is experienced when they are burned as mixtures. Changing the proportions in the mixtures will often prove helpful.

A conservatively designed boiler operated at full load continuously with the proper fuels and under good operating conditions is not unusual; in fact, most modern units do this regularly, many at high overloads. Older units, however, may have difficulty operating under these conditions. Consideration should be given to reducing the load on these older units whenever your schedule permits by either increasing the load on other units or by rearranging the plant requirements. It is realized that this is not always feasible, but, when possible, consideration should be given to this suggestion.

Many units, especially those equipped with water walls, will shed ash when rating is reduced. If there is exposed refractory between water-wall tubes shedding may not be very satisfactory. Advantage should be taken during periods of reduced loads to use any wall and screen tube blowers. Surfaces not reached by blowers should be hand lanced. Slag in furnaces, with exposed refractory between the tubes, can be greatly reduced by the addition of fins to the tubes. Depending on the design of the refractory, these fins usually are not too difficult to install.

It is most advantageous to operate boilers with the lowest excess air possible since theoretically it results in better boiler efficiency, but there is a practical limit to this decrease. Assuming a good tight setting and all the air for combustion enters through the burners and mixes completely with the fuel, the limiting amount of air would be determined by the resulting furnace temperature and its effect on the coal ash. Limiting of air increases furnace temperature in the burner zone and with the lower ash-fusion coals will be the starting of a slag condition. The slag starts in the burner area and on refractory surfaces and becomes progressively worse, affecting heat absorption in the furnace walls. The slag can turn from an easily removed porous substance to a dense solid or liquid state almost impossible to remove, thus affecting heat transfer. The zone of this deposit increases and can eventually cover most of the furnace area and results in high gas temperature leaving it. When this temperature leaving the furnace approaches that of the ash fusion, slag begins to form at the screen tubes and in the superheater and gradually builds up and eventually bridges over thereby restricting the gas lanes. The higher the temperature leaving the furnace, the higher will it be leaving the boiler and the lower will be the over-all boiler efficiency. There is a practical limit to reducing the excess air which should be determined by boiler performance. It must be remembered that decreasing excess air can increase fly-ash combustible loss as unburnt carbon in addition to affecting slag conditions.

Gas analysis at the boiler outlet is not always an indication of actual conditions in the furnace if there is any air leakage into the unit. Leakage is bad since it seldom takes part in combustion and in addition to affecting superheat and exit gas temperatures, can materially affect the burner performance and can result in abnormally high carbon dioxide around the lower part of a furnace. Air leakage influences burner performance, contributes to slag, generally causes increases of exit-gas temperatures, contributes to low boiler efficiency and induced-draft fan or stack capacity thereby a lowered boiler capacity. For these reasons, as well as many others, only minimum practical air leakage should be tolerated. Every effort should be expended in making a setting as tight as possible.

A good combustion control system should keep air requirement within a range of $\pm 2\%$. Variation of the controlled air leaving the burners gives varying carbon dioxide in the burner zone and can react against burner performance. Irregularities in supply of air affect flame pattern result in changes in carbon dioxide conditions with its attendant difficulties, can create a reducing atmosphere affecting softening and fluid temperature of the ash.

A poor combustion control system can materially affect slagging and must be given constant attention.

Burners are the heart of a boiler and should perform properly at all times. Their function is to correctly proportion the coal and air as they enter the furnace and anything that affects this function should be corrected.

Practically all burners have a refractory throat at the furnace inlet. Even under the best conditions slag can form on this surface because of eddying effects and should be cleaned off frequently since burner performance can suffer as a result. Some consideration should be given to the use of a carborundum refractory in this area. This material will minimize slag formations and that which does form can be more easily removed by hand lancing or shedding.

Burners should be checked frequently to insure proper distribution of air around the coal nozzle to assure proper distribution of the fuel as it leaves the nozzle. A discrepancy in these mixtures can lead not only to unstable ignition but also to poor mixing of fuel and air and poor combustion conditions. All are factors tending to the development of slag.

In some of the modern installations temperature of feedwater entering the boiler is fairly high because of the use of high-pressure heaters in the system cycle. When a heater is removed from service, for any reason, the feedwater temperature is lowered. Aside from affecting steam temperature, lowering of feedwater temperatures requires that the fuel input be increased if normal rating is desired of the boiler. Unless this fuel increase is recognized and instructions issued to the operating personnel for a corresponding increase in air required to burn this extra fuel, a deficiency of air results. Oftentimes decreased feedwater temperature can result in overloading of the boiler.

An attempt has been made to discuss the factors tending to cause slag. We might now consider its removal. The most common methods are: (1) hand lancing, (2) reducing boiler rating, and (3) soot blowing.

Hand lancing using rods is rather difficult and hazardous. It serves only to remove extremely large and hard deposits and then only in a limited area depending on the length of the rod.

Hand lancing using compressed air is considerably more effective because larger areas can be covered. The success of hand lancing with compressed air depends upon the cooling effect of the air, the air velocity, and volume of air used. Large quantities of air keep the lance tube cool in addition to cooling the ash which assists materially in slag removal.

Water should not be used except in emergency. Continued use of water can deteriorate refractory and insulation and may cause leakage of rolled joints. Continued use of water has resulted in "elephant hiding" of tubes. If water is used it is recommended that extreme care be employed.

The most successful, safe, and easiest means for slag removal is by means of soot blowers. These are most successful, excepting perhaps in the case of slag in the sticky or wet stage. To be successful wall blowers should have a well-designed nozzle, either the single or double type, should operate above 150 lb. pressure, and rotate at slow speeds. This slower speed allows the air or steam to partially cool the slag and make it easier to remove. Proper location of the nozzles in relation to the plane of the walls is most important.

Retractable or telescopic-type blowers at the inlet to screen tubes and superheater have proved most successful. Hand lancing these surfaces is rather difficult and the results never completely satisfactory, even when access doors are provided.

Retractable blowers generally operate above 150 lb. pressure. A properly designed nozzle can remove most slag deposits unless they have been allowed to bridge over. It is most important that cleaning be effective over the entire area of a superheater. If slag deposits remain in tube lanes it can result in gas stratification and possible loss of elements due to overheating. The retractable blower element is seldom susceptible to sulphur and/or vanadium attack because when not in use it is removed from the high temperature zone of the furnace. Probably the most definite advantage of this type blower over the fixed type, however, is that it is considerably more effective in slag removal because a greater volume of air or steam, at higher pressure, is used. The rotating fixed type consists of a series of approximately $^3/_8$-in. nozzles along the length of the element. These nozzles are usually set to blow between the open lanes but, due to tube movement and expansion of the element, this is never a certainty. When one or both change it can result in impingement of the blowing medium on tubes and eventual erosion of tube surfaces.

When not in use the fixed type of soot blowing element collects fly ash that acts as an abrasive when the blower is placed in service. A retractable element can concentrate as much as four times as much air or steam at higher pressure on the surfaces to be cleaned and can remove deposits that the fixed type can never remove. Because it blows for only a short time at any fixed spot, the erosion problem is greatly lessened.

Elaboration on all the many factors enumerated has, of necessity, been very brief. Practically each item in itself is worthy of a long discussion.

Slag is not insurmountable and with reasonable care and some thought it can be kept under control.

Design Considerations—Clifford L. Noll (Foster Wheeler Corp., New York, N. Y.)

Slag problems in steam generators are symptoms of basic disorders. Therefore, whenever possible, it is desirable to eliminate the cause rather than to treat the symptom. This can be accomplished with the most certainty and the least expense at the time the steam generator is designed.

The two basic types of slag found in steam generators are: (1) that due to softened ash, and, (2) that due to a reaction between the products of combustion.

Most familiar is the melted ash type of slag. This appears most commonly in coal-fired units and is confined to areas where the temperature of the particle is higher than the softening temperature of the ash. Here gas temperature is, of course, of critical importance; but particle temperature often differs from the temperature of the gas in which it is carried. A large fuel particle naturally requires a longer period of time for complete combustion than a small one, and the particle will remain at a temperature above that of the gases until combustion is completed and only the ash remains. The ideal fuel, of course, is one which is composed of an infinite number of infinitesimal particles. This small fuel mass per particle makes it possible for the combustion air to mix intimately with the fuel. From the slagging viewpoint, small particle size is desirable for another reason. It has been found that in a reducing atmosphere the softening temperature of a given ash is lower than when in an oxidizing atmosphere. Thus, fine particles and an intimate mixture of fuel and air not only help to reduce particle temperature quickly but they also help to raise the temperature at which the ash becomes adhesive and troublesome. We see then, a definite relationship between the size of a particle and the time interval during which it should remain in the furnace. A fuel particle should not enter any convection area until its combustion is completed and it has cooled below the ash softening temperature for the atmosphere (reducing or oxidizing) which exists in the furnace. Furnace volume is often used as an index to the relative combustion time interval provided by two furnaces. For furnaces of similar shapes this is a method of approximate comparison. However, if we visualize two furnaces of equal volume, one cubical and the other vertically elongated, there can be no question that the latter is to be desired because in it, each particle is exposed to a greater cooling area and it provides a better location for the convection surface slag screen—that is, a location that is further removed from the center line of the burners.

We know also that slag adheres much more tenaciously to refractory surfaces than to steel tubes. Further, there are certain compounds which, when present in ash, act as fluxing agents and serve to aid the agglomeration of the particles. An example of this is a coal from a strip mine at Atkinson, Ill. While the fluid temperature of this coal was approximately 2300°F., the ash fused so badly on the grates that the tuyeres of the stokers became clogged in a very short time. It was believed that this condition was caused largely by the fluxing effect of oxides of calcium, magnesium, sodium, and potassium and the incomplete oxidation of iron and sulphur in this reducing atmosphere.

Gas velocity also has an important bearing on the slagging problem. It has been found that slag accumulation beyond the furnace occurs most frequently in convection areas where both gas temperature and velocity are high. It appears that above a certain velocity the impact of the particle striking the tube is great enough to make it stick to the tube.

Summing up, then, the conditions most closely allied to slagging of steam generators are: (1) gas temperature, (2) fuel particle temperature, (3) fuel particle size, (4) furnace size and configuration, (5) furnace atmosphere, (6) composition of ash, and (7) gas velocity.

Let us consider now the design of a slag-free steam generator remembering these conditions.

First, from a slag viewpoint it is always desirable to maintain low gas temperatures in the convection zones. In high pressure, high temperature units with wide temperature control ranges, this conflicts with the thermodynamic demands of the unit. Some compromise must be found which will provide low gas temperatures in the convection zones and still maintain heat heads high enough to transfer the required heat economically. Several methods devised to accomplish this are now in practice. One method is to accomplish in the furnace some of the work that is customarily done in the convection zones. This is done in the combination radiant-convection superheater. Although its primary advantage is its wide control range with extremely flat load-temperature characteristics, it has a further advantage in that it reduces the amount of convection duty required. Consequently, the gas temperature entering the convection zone may be reduced without loss in heat head and the possibility of slagging due to too high gas temperature is minimized.

Burner design is of critical importance for a slag-free unit. Burners should be of a design that provides a high degree of turbulence so that each fuel particle is continuously swept by combustion air. There can be no compromising high turbulence for low pressure drop without the accompanying reduced combustion rates and the risk of incomplete combustion. Burners should provide uniform distribution of fuel so that there is an intimate mixture of fuel and air at the burner exit and there should be adequate control of flame shape to prevent impingement of flame on the furnace wall.

As we have seen before, fuel particle size has a direct effect on slagging. There is a practical limit, of course, to the fineness of fuel leaving the pulverizing equipment and nearly all present types of pulverizing mills are able to produce this optimum fineness when initially put into operation. However, due to inherent design features, the low speed type of ball mill not only provides the fineness required initially but it is capable of delivering fuel of constant high fineness throughout the life of the pulverizer unit. This is accomplished merely by maintaining the required ball charge which can be done periodically while the unit is operating.

Furnace shape also has a direct effect on slagging tendencies. The furnace should be large enough so that all fuel particles have completed their combustion before entering the convection zones. There should be adequate clearance between burners and water walls to prevent impingement of the flame and its entrained particles on the cooling surface. Inasmuch as slag adheres very strongly to refractory surface there should be a minimum of exposed refractory in the furnace. The gas velocities through convection surfaces should be kept as low as possible and the tubes should be on wide centers in the high-temperature convection zones. The high-temperature convection section should be arranged so that any deposits which may occasionally appear can be blown back into the furnace or otherwise removed without having to be blown through the entire convection area.

With some coals moderate slag accumulation can be controlled with ease and it presents no critically serious problem in a properly designed furnace. When slagging disturbs neither the furnace equilibrium nor the flow of gases over convection surface, it usually is of little consequence. However, progressive slag accumulation in furnaces or any deposit in the convection zone is sure to upset the thermal equilibrium of the unit and steam generators must always be *designed* to prevent this from occurring.

LITERATURE REFERENCES

Walsh, E. F., "Some Aspects as to the Cause and Prevention of Slag Deposits on the Heating Surfaces of Modern High Pressure Boilers," ASME, presented May 2–4, 1949.

Frisch, Martin, "Steam Generating Equipment for Resuperheating Cycles," *Transactions ASME*, 71: 707–717 (1949).

TAPPI Fibrary

Addendum II

THIS catalog is the third to be published for the TAPPI Fibrary, for which collection efforts were initiated in October, 1949. (See *Tappi* 34, No. 2: 26A, Feb., 1951, and 35, No. 9: 178A, Sept., 1952, for the previous lists.) There are still many fibers which are needed. It is hoped that contributions of missing species will be forthcoming from TAPPI members so this fiber collection may continue to enlarge and increase in value. Further addenda to this index will be published as occasion requires.

A representative specimen of each fiber may be obtained from the Fibrary, The Institute of Paper Chemistry, Appleton Wis. Each sample has a number which may be used in ordering. A service charge of 25 cents ($0.25) per sample has been established to help defray the cost of handling, packing, and postage. Remittance of the necessary fee at the time of ordering will help to keep these costs as low as possible.

The custodians of the Fibrary have checked, to the best of their ability, all fibers submitted, as to species and process. Please write them if any error is detected.

The amount of pulping data given by the donor varies considerably in different samples. Because of space limitations many of the details which have been sent with the sample will not be published but will be filed with the sample for reference purposes. Naturally, it is desirable to have complete details, if available.

No acknowledgment has been made in the catalog to the donors for the various samples. In many instances several companies or individuals offered the same fibers and while duplication is inevitable, every effort was made to avoid it to conserve space without decreasing the effectiveness of the fiber collection. Unquestionably, the gratitude of the industry is due these anonymous donors.

Fibrary, Addendum II

No.	*Species*	*Location grown*	*Process*	*Degree of cooking*	*Bleaching*	*Remarks*
360	Aspen (*Populus tremuloides*)	Michigan	Groundwood	....	Full	Hypochlorite bleached
361	Aspen (*Populus tremuloides*)	Michigan	Sulphite	Medium	None	
362	Aspen (*Populus tremuloides*)	Michigan	Sulphite	Medium	Full	
363	Basswood (*Tilia americana*)	Wisconsin	Sulphite	Medium	None	
364	Basswood (*Tilia americana*)	Wisconsin	Sulphite	Medium	Full	
365	Basswood (*Tilia americana*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	None	
366	Basswood (*Tilia americana*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	Full	Three-stage bleach
367	Cherry, black (*Prunus serotina*)	Wisconsin	Sulphite	Hard	None	High screenings
368	Cherry, black (*Prunus serotina*)	Wisconsin	Sulphite	Hard	Full	28% yield
369	Cherry, black (*Prunus serotina*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	None	
370	Cherry, black (*Prunus serotina*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	Full	Three-stage bleach
371	Date palm leaf (*Phoenix dactylifera*)	Iraq	Neutral sulphite semichemical	45% yield	None	
372	Hophornbeam (*Ostrya virginiana*)	Wisconsin	Sulphite	Medium	None	
373	Hophornbeam (*Ostrya virginiana*)	Wisconsin	Sulphite	Medium	Full	
374	Hophornbeam (*Ostrya virginiana*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	None	
375	Hophornbeam (*Ostrya virginiana*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	Full	Three-stage bleach
376	Maple, hard and soft (*Acer* sp.)	Ontario	Sulphite	Medium	None	
377	Oak, red (*Quercus rubra*)	Wisconsin	Sulphite	Medium	None	
378	Oak, red)*Quercus rubra*)	Wisconsin	Sulphite	Medium	Full	
379	Oak, red (*Quercus rubra*)	Wisconsin	Neutral sulphite semichemical	Low yield	None	
380	Oak, red (*Quercus rubra*)	Wisconsin	Neutral sulphite semichemical	Low yield	Full	Three-stage bleach
381	Oak, white (*Quercus alba*)	Wisconsin	Sulphite	Medium	None	
382	Oak, white (*Quercus alba*)	Wisconsin	Sulphite	Medium	Full	
383	Oak, white (*Quercus alba*)	Wisconsin	Neutral sulphite semichemical	Low yield	None	
384	Oak, white (*Quercus alba*)	Wisconsin	Neutral sulphite semichemical	Low yield	Full	Three-stage bleach
385	Para rubber tree (*Hevea brasiliensis*)	Liberia	Kraft	Soft	None	
386	Pine, ponderosa (*Pinus ponderosa*)	Washington	Kraft	Medium	None	
387	Pine, shortleaf (*Pinus echinata*)	Alabama	Kraft	Soft	None	
388	Poplar, balsam (*Populus balsamifera*)	Ontario	Neutral sulphite semichemical	Intermediate yield	None	
389	Willow, black (*Salix nigra*)	Wisconsin	Sulphite	Medium	None	Ammonia base
390	Willow, black (*Salix nigra*)	Wisconsin	Neutral sulphite semichemical	Intermediate yield	None	

RECENT BOOKS

Design and Analysis of Industrial Experiments. Edited by Owen L. Davies. Hafner Publishing Co., New York, 1954. Cloth, 6 × 10, 637 pages. $10.

The present volume was prepared by G. E. P. Box, L. R. Connor, W. R. Cousins, O. L. Davis, F. R. Himsworth, and G. P. Sillitts for Imperial Chemical Industries, Ltd., who has long recognized that statistical methods have an important part to play in industrial research and production. It is a sequel to "Statistical Methods in Research and Production" by the same editor.

It is not intended as a general treatise on industrial research but deals with one aspect of it, namely, the arrangement of the individual items composing a complex experiment designed for a specific purpose and the statistical analysis of the results.

It stresses the fact that whenever a problem involves the use of data which are subject to appreciable experimental errors, statistical methods offer the only sound and logical means of treatment. To understand the text the authors assume an elementary knowledge of statistics on the part of the reader.

Package Engineering. By Louis C. Barail, consulting packaging engineer. Reinhold Publishing Co., New York, 1954. Cloth, 6 × 9, 416 pages. $9.50.

A good packaging engineer should know all of the intricacies, short cuts, labor and money saving methods, and devices. He should be able to improvise quickly in any problems dealing with corrosion, mildew, insect, or rodent prevention; packaging or packing materials and methods; shipping conditions; insurance; and pilferage, in order to insure the quickest delivery of goods in perfect condition at minimum cost.

Among the subjects covered are prevention of corrosion, prevention against microorganisms, insect and rodent resistance, package design, size, shape, and color testing methods, baling, fiberboard containers, paper bags, cushioning, closures, plastics, adhesives and coating agents, printing inks, machinery, paper food containers, packaging for export and armed forces.

Forest Products Research Society Annual Proceedings. *Journal of the Forest Products Research Society*, Vol. IV, No. 5, October, 1954 (Box 2010, Madison, Wis.). Cloth, 236 pages. $9.00.

An account of the FPRS Eighth Annual Meeting, Grand Rapids, Mich., May 5–7, 1954, containing 43 papers on packaging, wood composition board, glues, quality control, and general subjects. Since the meeting was held at Grand Rapids, emphasis is given to the furniture industry.

Materials for Product Development—1954. Clark & Poliak, Inc., New York, 1954. Fabricoid, 6 × 9, 159 pages. $7.50.

The Second Basic Materials Exposition and Conference was held in Chicago in May, 1954. At this conference a number of papers were presented.

Some of the subjects considered were the development of engineering materials, precision coatings, powder metallurgy, plastics, ceramics, glass, adhesives, protective coatings for steel and materials departments. Most of the developments referred to related to the past year.

Note: Books reviewed in this column may be obtained from the Technical Association of the Pulp and Paper Industry, 155 E. 44th St., New York 17, N. Y.

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Note: Responses to all advertisements should, unless otherwise indicated, be sent to TAPPI, 155 E. 44th St., New York, N. Y.

LOCAL SECTION ACTIVITIES

Reports of Meetings, Personnel, and Events

New England

A meeting of the New England Section of TAPPI was held on Dec. 10, 1954, at the Roger Smith Hotel in Holyoke, Mass. About 125 people attended.

Preceding the meeting, mill visits were held at the Albion and Crocker Divisions of the American Writing Paper Corp. in Holyoke. The Crocker Division is a manufacturing unit, while the Albion is a finishing operation.

Following the mill visits, two talks were presented. The first of these by Horace N. Lee, instructor of paper engineering, Lowell Technological Institute, Lowell, Mass., who discussed "3-D Microscopy." John N. McGovern of Parsons & Whittemore, Inc., New York, N. Y., then talked informally on "Some of the Newer Fibers and the Properties They Impart to Paper."

Dinner was followed by movies, one of which was taken at the Annual Meeting at Oceanside Hotel, Magnolia, Mass., June 11–12, 1954.

R. W. Ramsdell, *Secretary-Treasurer*

3-D Microscopy

Horace N. Lee

After a dozen or more years sojourning mostly in the textile field I find myself suddenly again plunged into the intricacies of paper microscopy. These intricacies used to be sufficiently mystifying, it would seem, to almost anyone. Now, with the ever-increasing kinds of wood raw materials and methods of chemical preparation that are being used, it behooves the microscopist to make use of every possible aid and assistance to help him in the increasingly difficult tasks which present themselves in both pulp and paper.

This presentation offers some suggestions along this line and throws in a few observations as to how a specific equipment may be used to advantage. In some instances such an instrument is essential, in many cases it is merely the most convenient, while sometimes it only brings results most directly and quickly.

Now what is this very present help? Is it a gadget to add to your present microscope to make it more complicated and difficult to operate? No, it is a well-known, long used and, in recent years, effectively improved instrument, the wide-field, steroscopic microscope, hereinafter referred to as the stereo microscope. Such microscopes have long been in use but not so much in the paper industry. To those of you who are equipped with a good variety of microscopical instruments I can probably add little, if any, to your store of useful knowledge. But, if you have not been actually using one of these instruments, you are certainly not treating yourself, or anyone depending on you for information, fairly, when you try to force an ordinary monocular to do the work of a stereo microscope. Just a few illustrations may be offered.

FIBER EXAMINATIONS

In fiber examination, the opportunity is afforded to observe quickly and efficiently the size, shape, cutting, coarse fibrillation, and mechanical alterations, in general, which are so important in relation to physical properties of papers. Such examinations, especially when made to compare satisfactory and unsatisfactory products, are not infrequently sufficient to establish good evidence for solving very expeditiously some otherwise difficult problems.

The opportunities of examining desirable and undesirable structural conditions in papers are becoming increasingly apparent. Microscopy in research and in routine testing of metals has grown from nothing to commonplace in the last 30 years. More recent advances in textile engineering, the study, planning, and designing of fabrics as structural materials, presage more attention to this subject in relation to paper structure In some instances the stereo microscope will be invaluable for such investigations, largely because of the three-dimensional images which it shows.

FIBER IDENTIFICATION

The time when a few hours were sufficient to enable one to become acquainted with the virtues of the Herzberg stain and thus become a fully trained paper analyst is long past. In these times one could easily spend days, weeks, or even months in mastering the effects of those staining procedures listed in TAPPI Standard T401 and in the TAPPI Routine Control Methods alone. Each of the many methods now available have their qualities and uses. Unfortunately, it sometimes seems that when several different but similar methods are used the results lead to confusion rather than to clarification.

At the present time there is probably no one more widely useful stain than Graff's C stain.

May I here pause to pay a tribute to John Graff? I first met him nearly 40 years ago in Berlin, N. H., where the Brown Co. was interested in establishing microscopical methods. John was just starting his work with no previous training in the subject. I know he had no further instruction other than that of his own efforts. You all know what he accomplished.

The C stain is the best of all for initial examinations of unknown samples covering all or a large part of the whole field of paper fibers. At times it may be difficult with the C stain to establish precisely the pulping process used. This can be because of the narrow range of differences in shades or because of mechanical or chemical effects on the fibers in the course of processing for papermaking which causes color variations. In such cases checking by means of one or more specialized stains is advantageous. Furthermore any information which can be obtained by recognition of the structural characteristics, pitting in the fibers, types of vessels or pores in hardwoods, and size and shape, frequently add enough to the data from staining to establish the identity when the staining alone might give doubtful results.

Whether it is structural features or the recognition of shades of colors, the stereo microscope, provided with a suitable source of light, will present the fibers with a degree of distinctness and clarity which is possible only when a stereoscopic image is visible. It truly must be seen to be appreciated.

In addition to contributing to a greater degree of precision, it makes continued work much easier on the eyes. In fact, both eyes are not only capable of being used but they *must* be used to secure a proper image. One not thoroughly accustomed to the use of a monocular microscope is likely to close the unused eye. This results in unnecessary strain and fatigue.

Another cause of both eyestrain and conditions making it

Horace N. Lee, Paper Engineering Department, Lowell Technological Institute, Lowell, Mass.

difficult to see images easily in the microscope is the presence of glare. Many of the lamps commonly used with monocular microscopes cause considerable glare. The stereo microscope, using magnifications to only about 100 diameters, makes use of nonglare light sources possible. Indeed, for some uses, such light is essential.

MISCELLANEOUS MATERIALS IN PULP AND PAPER

It was originally intended that this presentation would be limited to fiber analysis examinations, as in these alone the advantages of the stereo microscope are clearly evident. But if one is fully satisfied that other equipment is adequate for such studies the fact remains that the stereo microscope can claim that it is important and even essential for other purposes.

One of these relates to identification of dirt specks and other defects in pulp or paper. In addition to making an understanding of these easier because of the stereoscopic image, the stereo microscope permits efficient handling of small objects with needles because of the distance (an inch or more), between the objectives and the objects, and particularly because the image as seen is not reversed. It is not easy to work with needles at even low magnifications, if every move is recorded as opposite to that which is made. This is the case with the monocular microscope. With the stereo microscope, the removing, uncovering, or otherwise treating specks or other objects is not only easier but examination is made possible where it could not be efficiently accomplished otherwise. Attempts to handle or to remove some objects are futile while being observed with the monocular microscope.

EXAMINATION OF PRODUCTION EQUIPMENT

Another type of examination where the stereo microscope is invaluable is in cases where production equipment requires examination while in its use position. For this the base of the stereo microscope can be removed and the tube held or supported so that the limited area requiring attention may be observed even if it is in a rather inaccessible position.

EXAMINATION OF PAPER PRODUCTS IN RELATION TO USE

Examples of another type of use are almost without limit. These include all kinds of examinations of paper products in relation to use. The opportunities of establishing the relationship of surface to use are legion. Perhaps the most common of these is in connection with printing. The vividness of the images and the clearness with which they can be understood in relation to the paper surfaces can hardly be believed until they are seen.

CONCLUSION

In conclusion, the stereo microscope is presented as being more comfortable and efficient to use, to give more easily interpreted images, or to be absolutely essential for a wide variety of purposes in the pulp and paper industry; ranging from examinations of raw materials, all stages in the processing of materials, the equipments used in processing, and the final product before, during, and after use.

October Meeting

The following paper was presented at the Oct. 8, 1954, meeting of the New England Section.

The Properties and Commercial Use of Papermakers' Alum

John P. Bainbridge, Jr.

Alum has been used by papermakers in much its present form for over 100 years. Mills are now becoming more and more interested in alum, particularly about the use of liquid alum, acid-alum, and other forms of this important chemical. A discussion of its composition and handling is, therefore, in order.

This paper is intended to give mainly the practical aspects but in order to understand the practical aspects it is necessary to go into the chemistry of alum and its manufacture at least briefly.

TERMINOLOGY

"True alum" is a double salt of aluminum and potassium—$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$. Papermakers' alum is the aluminum salt only and, furthermore, it is not the true crystal product. The crystal product would be $Al_2(SO_4)_3 \cdot 18H_2O$ and would contain about 15.7% Al_2O_3. The papermakers' form has only $14\frac{1}{2}$ waters of crystallization and contains 17.2% Al_2O_3.

To the paper mill chemist, alum is a dry chemical and he thinks of solutions in terms of pounds per gallon or per cent of dry alum. The alum manufacturer, on the other hand, thinks of alum in terms of per cent alumina and the "basicity." The use of that terminology will simplify thinking concerning alum. Basicity is the molecular relationship between the alumina and the sulphuric acid present. An acid alum is one having excess sulphuric acid, a basic one is deficient in sulphuric acid, and, of course, a neutral alum has stoichiometric proportions of alumina and sulphuric acid.

On this basis, commercial dry alum can be described as one having 17.2% total alumina, and which is slightly basic to the extent of 0.7% uncombined Al_2O_3; that is, 16.5% combined Al_2O_3, 0.7% basic Al_2O_3, and 17.2% total Al_2O_3. The amount of sulphate can be figured from that, and usually runs about 40% as SO_3 or almost 50% as H_2SO_4. Therefore, if a pound of alum is added it is equivalent to adding a half-pound of H_2SO_4.

MANUFACTURE

Alum is made from bauxite and sulphuric acid. Bauxite is hydrated aluminum oxide, usually with a formula $Al_2O_3 \cdot 2H_2O$. It is obtained both domestically and from British Guinea and is a decomposition product of feldspathic rock. It has silica as an impurity, indicating clay origin. A typical South American bauxite has the following composition:

Al_2O_3	60%
SiO_2	$2\frac{1}{2}$%
Fe_2O_3	$1\frac{1}{2}$%
Titanium	2 to $2\frac{1}{2}$%

The bauxite is ground, reacted with sulphuric acid, the iron in the solution reduced with aluminum dross, or other reducing agent, insolubles settled or filtered out, and the solution boiled down to final composition. It is then allowed to harden, usually on large crystallizing pans. The solidified cake is broken up, ground, and finally packaged in bags; all for a price equal to only one-third the market value of a bleached sulphite pulp.

The product is not a true crystal. It is rather a solid solution. In other words, there is no crystallization from a solution, but rather a solidification on cooling. Furthermore, if the true $18H_2O$ crystal were permitted to form, the product would be so tough as a crystal mass that it could not be ground in conventional grinding equipment.

Alum is also produced from clay and other raw materials which will be discussed briefly at a later point.

Commercial Product

Dry alum from all manufacturers is virtually identical and from the point of view of commercial use runs very uniform; in fact, complaints stemming from a variation in the composition of alum are very rare.

Why does alum have the composition it does? Is it that exhaustive research and mill experience have shown that the present composition gives the best sizing and papermaking

John P. Bainbridge, Jr., Monsanto Chemical Co., Boston, Mass.

results? Such may well be the case, but there is no evidence of it. On the contrary, the answer would seem to be that the present composition makes possible the most uniform and economical manufacture.

There seem to be three sound reasons for the present composition of the dry product: (1) An alum of a different alumina composition may be virtually impossible to grind, as would be the true crystal form. (2) If the alum is made with excess acid there is danger of an insoluble acid alum crystallizing out of solution during manufacture, causing difficulty. Whenever acid alum solution of high concentration (8% Al_2O_3) is used care should be taken of this feature. (3) An alum containing excess sulphuric acid will cause carbonization and deterioration of burlap or paper bags used for packaging. This seems to be one of the major reasons for a slightly basic alum.

It is evident, therefore, that from a purely papermaking point of view, other forms of alum *might* be more advantageous. It should not be taken for granted that a century of papermaking has proved the value of any specific composition.

Types of Alum

The types of alum which may or may not be available commercially are described below:

1. *Commercial alum* having the following composition:

Total Al_2O_3	17.2%
Combined Al_2O_3	16.5
Basic Al_2O_3	0.7
Insoluble	0.07
Fe_2O_3	0.01
FeO	0.35

2. *Liquid alum:* liquid alum may be considered to be the solution for the manufacture of commercial alum before it has been boiled down to make the dry product. Therefore, it is cheaper but much the same as the dry product. A typical liquid alum contains 8% Al_2O_3, or 46.5% dry alum equivalent. Calculating the relative value of a liquid alum, the easiest method is to consider the proportions of alumina in the liquid to 17.2% normally in the dry product. Liquid alum is shipped in tank cars and in tank trucks and may be stored in equipment designed for handling alum solutions, as discussed later.

3. *Iron-free alum:* this is a much more expensive product since it is made from purified aluminum hydrate. The latter is usually made by Bayer process which consists of dissolving bauxite in caustic soda, filtering, and precipitating the alumina with CO_2. The composition of iron-free alum is very similar to that of dry commercial alum, but it contains only 0.01% Fe_2O_3, and no FeO.

4. *Slab alum* (Spence alum): this product is not commercially important at present, but was used to a considerable extent in years past. As the name indicates, slabs or bricks of alum were prepared and shipped unpackaged. This product contained not over 16% Al_2O_3, in order to take advantage of the increased toughness of alum when it is prepared in the form of a crystal mass. The product was used in the Spence dissolver which makes use of natural circulation from a pile of slabs.

5. *Crude alum:* this is prepared by dissolving bauxite in sulphuric acid at the final concentration. There is, of course, danger of crystallization at the higher strengths and temperatures; therefore, there is no time for analysis or adjustment of the batch before it must be run out into the crystallization pan. Consequently, the product contains all of the impurities in the bauxite with insolubles running from 15 to 5%. Furthermore, and possibly more important, the composition varies tremendously. Fortunately, the industry has graduated from such a crude material having found that the very small savings could not justify possible loss of large amounts of paper or paperboard.

6. *Kamig alum* is prepared from clay and sulphuric acid, usually at the paper mill. A lead-lined autoclave is usually used. The nonsoluble residues, mainly silica, are available as fillers. These are advantageous in certain types of paper, but of course, have disadvantages in others.

Clay is also used by some commercial manufacturers of alum. The product usually contains a high percentage of potassium sulphate which reputedly is harmful to sizing. Potash alum ($K_2O \cdot Al_2O_3 \cdot SO_4 \cdot 24H_2O$) can be precipitated out from clay alum and an alum low in potassium produced from the filtrate. The potash alum has a limited market in other fields.

7. *High basic alum*, a soluble alum with a composition $Al_2(SO_4)_2(OH)_2$ can be produced with an Al_2O_3 content up to 32%. This has never been produced commercially but mill trials have indicated that it might have commercial importance. It permits the reduction by 33% in the amount of sulphate added to the beater and of course, makes possible a saving in sulphuric acid and shipping costs. The potential advantage of such a product versus a neutral alum or an acid alum is discussed later.

There are still other forms of alum, but since they are used for fire extinguishers or other purposes rather than papermaking, they will not be discussed here.

HANDLING

The handling of alum is quite simple. This probably explains why there is not more information on the techniques used.

Dry Alum

Dry alum is shipped in 100-lb. net weight paper bags or in bulk. It can be supplied in finely ground or lump form. It is nonhygroscopic. Furthermore it has a very low heat of solution. These two properties account in a large measure for its ease of handling. It will dissolve in cold water but for practical purposes hot water is almost universally used. It does not tend to heat up the water as it dissolves, as would an anhydrous product. For instance, anhydrous ferrous sulphate when added to cold water tends to lump up into a gooey mass which is almost impossible to handle. On the other hand, if ferric sulphate is added to hot water it tends to heat the water still hotter with consequent danger of boiling and frothing over. Alum presents none of these problems. If it is allowed to settle to the bottom of a tank there will be some tendency to form a cake but this is soft, can be broken up quite easily, and at any rate will dissolve reasonably quickly.

Alum bags may be stored under almost any conditions other than that the bags would get wet with liquid water. High humidity is not particularly harmful and in fact the bags in which it is shipped would be more harmed by wetting than would the alum itself. It is not shipped domestically in wet-strength bags.

Methods of dissolving alum are as follows:

1. Dry addition to the beater. This is certainly the most simple but probably not the most economical. So far as is known, the efficiency of alum so added is as good as added when in solution form. Furthermore, the chances of any serious contamination through alum are rather nil. Many, many mills, some of them fine paper mills, use this technique. The major disadvantage which has been observed is that mills which add alum dry are limited to the addition of one whole bag per beater or possibly a half a bag. It is impractical for the men to weigh each beaterfull carefully and volumetric measures tend to become inaccurate. Wastage to the extent of at least 15% has been observed.

2. The most conventional and best method of dissolving alum is a tank equipped with a stirrer and supplied with hot water. The stirrer may be either a Lightnin' mixer type or a sweep paddle. The agitation need only be sufficient to keep the fine-ground alum from forming a layer on the bottom. A wooden paddle-type stirrer equipped with a stainless steel or a lead-lined shaft is quite adequate. Most mills use water 125 to 165°F. The usual strength for alum solutions runs on the order of 1 to

2 lb. per gal., or 12 to 23% dry alum basis. Concentrations much above 25% become more difficult to handle and errors in measuring are exaggerated. There seems to be no advantage in reducing the concentration below 10 to 12%. These solutions are stable indefinitely, and the storage tanks need not be heated. A solution of about 25% would have a freezing point of about 28°F.

3. Air or steam stirring are both used for stirring alum solutions. Steam is to be preferred since it will heat water at the same time it tends to stir. Air is satisfactory only if it is used in a sparger so that it is broken up into fine streams which will give real agitation as it rises through the solution.

4. Suspended basket. This is the principle of the Spence dissolver for slab alum and depends for circulation on the increase in specific gravity of the alum solution as the solid dissolves. Slab or lump alum may be suspended in a basket made from stainless steel, rubber-lined steel, or wood. The basket is immersed below the solution level so that as the alum dissolves, the solution so formed being heavier than water sinks to the bottom and creates a natural circulation. This technique can be supplemented by a stream of hot water and/or steam directed down into the basket or wooden section of the dissolver. Usually the basket should occupy one half of the horizontal area of the dissolving tank.

A typical alum dissolving system consists of a dissolver, which may or may not act as a supply tank. Frequently the alum is dissolved to a concentrated solution, pumped through a storage or supply tank, and diluted further to final concentration. For instance, the alum may be dissolved to 30% solids and then diluted to final concentration of, for example, 10%. From the storage tank it may be run by gravity or pumped through measuring systems and then to the beaters or pulp slurry.

The metering system for alum solutions will depend on whether a batch or continuous system is used. Where the alum is added in batch system, the conventional technique is to use measuring tanks. These are equipped with either a float-type indicating device or sight glasses. The latter are safe enough on measuring tanks (although not on storage tanks), providing the tank is in a position that the glass will not be broken. The loss of material, should one be broken on a measuring tank, will usually not be critical.

The metering device recommended for batch addition is a domestic water meter type equipped with a dial. These meters are based on exactly the same principle as the usual household water meter. There is a large dial and the number of gallons required per beater can be set on the dial. After setting the dial, the pump or valves are energized and that number of gallons is automatically fed into the system. Warning—the meter for dilute alum solutions should be of type 316 stainless steel; regular 18 and 8 type 304 stainless steel is not satisfactory. One meter for six or eight beaters is sufficient, since there can be shut-off valves at each beater and a schedule can be worked out whereby alum will be added to one beater only at a time. It is believed that such a system is much more accurate than the measuring tanks since it is very easy for a man to set a gage correctly, whereas a measuring tank usually requires that the operator either fill it to a predetermined level or empty it a certain increment.

There are numerous feeling devices for continuous addition of alum. Rotameters are quite satisfactory as are proportioning pumps. Again, the materials of construction should be selected to insure correct operation. pH controllers are an ideal method of controlling the continuous flow of alum solution to the pulp slurry. Usually, however, care should be taken that 80 or 90% of the alum will be added all of the time and the control be maintained on only 10 or 20% of the total. In other words, a controlling system wherein the alum will be either all the way on or all the way off should be avoided.

Testing. The most practical method of mill control of alum solution is believed to be the use of a Baumé hydrometer. Even this, however, will not give precisely accurate results. Three separate published tables of Baumé versus per cent alum have been compared and it was observed the solids concentration at 20 Baumé varied as much as 1%. This would amount to a 6% error.

The reason for these discrepancies is definitely not that the alum varies or that the original work was in error. Rather it is undoubtedly due to a difference in the per cent Al_2O_3 and basicity of the alum used in the analysis. An alum with 1% basicity would be expected to give a higher solids per point Baumé than would an alum that was completely natural. On the other hand, the variation in analysis obtained through this factor is very minor compared to the many other errors involved in measuring and feeding. By testing the alum solution, therefore, the papermaker can feel certain the alum solution is being prepared with reasonable accuracy from day to day.

Unlike the solutions of many pure chemicals, the solids determination cannot be run by simply boiling down the solution to dryness. Alum is a hydrate and the amount of water of crystallization will depend entirely on the way the solution is boiled down. In fact, if aluminum sulphate is crystallized at room temperature an entirely different crystal will form than if it is done hot. The literature reports that an aluminum sulphate containing 27 waters of crystallization will be formed at temperatures in the range of 32°F. Another practical method of determining the strength of alum solutions is given in TAPPI Routine Control Method 123. This method depends upon the titration of a phenolphthalein end point of the alum solution with 0.5 *N* NaOH. Again, if there is any wide variation in the basicity of the alum this method will give incorrect results but from a practical point of view it should be highly adequate.

Complete, quantitative methods for the analysis of alum are given in TAPPI Standard T-614. This includes a gravimetric method which, although recommended for legal disputes, is time-consuming, involved, and dependent upon excellent technique. The volumetric method or variations of it is that used by most of the alum manufacturers and is much more practical. On the other hand, it also is dependent on careful technique and is not recommended for control purposes.

Several years ago, under the auspices of the preparation of papermaking materials committee, a survey was made of the paper industry for methods of handling and testing alum solutions. The consensus seemed to be that the Baumé technique was the most practical.

Liquid Alum

Liquid alum is the practical and economical way of receiving and handling alum when distances permit the shipment of additional water in the solution. Liquid alum will vary in concentration with the manufacturer and conditions for shipment. Usually it will run about 50% dry alum. A typical liquid alum would contain 8.0% Al_2O_3 or 46.5% dry alum.

The economies of liquid alum versus dry alum depend on many factors, and because conditions vary so greatly in one mill as compared to another, an individual study should be made of each location. Two of the most important considerations are freight and handling costs.

With regard to freight costs the distances from manufacturers of both liquid and dry alum should be considered. Because of economies of manufacture, liquid alum will be priced lower than dry; on the other hand, it is necessary to transport about a pound of water for each pound of dry alum equivalent. Therefore, the relative economies at each location must be figured carefully in conjunction with the transportation companies involved.

The potential saving in the delivered cost of liquid versus dry alum is only part of the story. Of equal and possibly greater importance is that liquid alum is easier and less expensive to handle in the mill and savings in handling alone may justify its use. Naturally, the handling costs will depend entirely on the local situation, but an example based on engineering estimates may be of interest.

The following is a comparison of the cost of handling alum

in bags delivered at the mill with the cost of receiving liquid alum in tank trucks. Assume a hypothetical case of a mill which buys alum in 600-bag cars (30 tons) and that they unload the alum from the car using a fork truck and load it on to pallets; these pallets are then carried on a fork truck 200 ft. to storage; that the bags are stored palletized 20 bags each and that they are two pallets high. The material is then picked up by the fork trucks, carried 200 yd. to the dissolver where the bags are opened and dumped. A rough estimate of the cost per year of such an operation can be obtained without going into too complicated bookkeeping.

1. Unloading: Four men, a fork truck, and an operator for 3 hr. and 5 min., or $15^1/_2$ man-hr. and 3 fork truck hr.—cost, not including overhead, $0.25 per ton.
2. Storage Cost: Assuming 900-bag inventory, or 45 tons at $3.70 per yr. in a brick building, or a cost of $156 per yr.
3. Using the material by moving it 200 yd. by fork truck opening and dumping bags. This would require $1^3/_5$ man-hr. and $^3/_5$ of a fork truck hr. or a cost of $2.70 per ton.

Total cost for 1000 tons per yr., $4006.

These figures make a lot of assumptions, such as the cost of fork truck and operator at $2.25 per hr. and $1.75 per lb. for labor plus social security benefits, etc., and a cost of $0.35 per sq. ft. per yr. for storage space in a brick building.

The liquid alum cost has been estimated to require $1^1/_4$ hr. of an operator's time to unload a 3000-gal. tank car or truck. This would cost about 28¢ per dry ton. In addition, there may be a theoretical charge involving dilution of liquid alum to the strength used in the mill. Usually that is done with dry alum, and it was not included in the above estimate. Furthermore, in many instances the truck driver will unload the tank after receiving clearance from mill personnel. This cost, therefore, is estimated at $280 per yr. leaving a net saving of $3726.

This saving has no relation to any potential saving involved in purchasing the material in liquid form, but it is a cost which is not usually figured, but which is an important item.

One very important factor to be remembered in the use of liquid alum is that a storage tank of at least $1^1/_2$ times, and preferably two times, the size of the shipping tank must be installed. A mill receiving alum in 3000-gal. tank trucks should provide storage for 6000 gal.: 4500 gal. might suffice but it is strongly recommended that a 6000 gal. tank be installed. There is nothing quite so hard on mill personnel and the supplier as the necessity for scheduling delivery of a material to coincide with the emptying of a storage tank.

MATERIALS OF CONSTRUCTION

Alum solutions are corrosive and although steel and iron are not satisfactory for handling it, there is a wide choice of entirely satisfactory materials. Lead is excellent but rather expensive. Unless lead burners are available, lead-lined tanks are not recommended. One practical thought in connection with lead is that it has a very high salvage value, and its initial high cost is potentially compensated thereby. Duriron, or other high silicon steel, pumps, and piping are considered excellent.

Wooden tanks are quite satisfactory. Cypress is the recommended material. Wooden tanks have been in operation in an alum plant for as long as 30 years and have given excellent service and low maintenance. The biggest objection to wood is that when the tank level drops, the wood up top dries out and weeping occurs when the tank is next filled. Furthermore, there may be some separation of the wood by crystal formation. By keeping the tanks tightly covered and occasionally washing them off, this factor can be minimized. The installation should provide for proper drain so that unsightly conditions will not be obtained.

As mentioned previously, ordinary stainless steel is not recommended but type 316 (18 and 8 molybdenum) is entirely satisfactory. Rubber-lined or coated steel is entirely satisfactory and widely used. The manufacturer will supply the temperature limits of such an installation. Many plastic linings and fittings are excellent. Plastic valves are supplied that are extensively used.

For tanks, lining with acid-resistant tile is highly recommended for an excellent job. Acidproof brick, on the other hand, sometimes is found wanting because there is the possibility that the alum will crystallize behind the bricks and cause deterioration.

This is not a factor unless highly concentrated solutions are handled. Excellent service may be expected of pipe lines made of Duriron, lead, rubber-lined steel, or many plastics. One type of piping which is very practical is ordinary rubber hose of the garden variety. These have almost infinite life, are inexpensive, are cheap to install, and have essentially no maintenance. Probably the only feature against them is that they are not too good looking.

In summary, therefore, an excellent system for receiving and handling liquid alum can be visualized as follows:

1. Storage tank and dilution tank of steel with acid-resistant tile lining.
2. Duriron or lead pumps.
3. Pipe lines of rubber hoses.
4. Valves of polyvinyl chloride or rubber diaphragm type.
5. Metering device of the Buffalo meter type made of 316 stainless steel.
6. Alum, strength of 1 to 2 lb. per gal. checked by Baumé hydrometer.
7. Provided the tanks and equipment are indoors under conditions that water will not freeze, no precautions against crystallization or freezing need be taken.

FUNDAMENTAL REACTIONS OF ALUM

Some of the fundamental reactions are given as follows:

1. $Al_2(SO_4)_3$ and $6HOH \rightleftarrows 2Al(OH)_3$ and $3H_2SO_4$.
2. $Al_2(SO_4)_3 \rightleftarrows Al^{+++}$ and $3SO_4$.
3. $Al_2(SO_4)_3$ and $6NaOH \rightleftarrows 2Al(OH)_3$ and $3Na_2SO_4$.
4. $Al(OH)_3$ and $3H^+ \rightarrow Al^{+++}$ and $3H_2O$.

In reaction no. 1 it is seen that aluminum sulphate in water can form aluminum hydrate and sulphuric acid. Since sulphuric is much stronger acid than aluminum hydrate is an alkali, the material gives an acid reaction.

In reaction no. 2 is seen the reaction which is believed to be the most important to paper sizing, that is, the ionization in solution of aluminum sulphate. It is obvious that any unnecessary addition of sulphate ion will cause this reaction to move to the left, causing a decrease in the concentration of available aluminum ions.

In reaction no. 3 it is seen that when alum is added to a caustic solution or vice versa, we get precipitated alumina and sodium sulphate in solution.

Reaction no. 4 is highly idealized and shows that if there were such a thing as pure hydrogen ions, aluminum ions could be formed without the usually harmful anion. Unfortunately, it is impossible to produce laboratory quantities of pure hydrogen ions, much less tank car quantities.

A well-known reaction, but one which is not too well remembered, is that when aluminum hydrate is precipitated from alum solutions the exact composition of the precipitate will vary with the pH and the concentration of the solution. That is, if alum is precipitated and the reaction actually takes place at 6.5 pH, almost pure aluminum hydrate will be formed although there will be some occluded sulphate. When alum is precipitated at 5 pH, on the other hand, there will be a considerable portion of sulphate in the actual chemical precipitate; that is, it will be an acid aluminum hydrate or a basic aluminum sulphate. It might have the composition, for instance, of $Al_2SO_4(OH)_4$. Therefore, when we cause precipitation of alumina from papermaking solutions, we are removing from the solution some of the sulphate, as well as the aluminum.

Alum performs two functions in sizing paper. First, it adjusts the pH or acidity of the pulp slurry, and secondly, it

supplies a source of potential aluminum ions. It is apt, therefore, again to ask the question—is the present commercial alum the optimum material for this purpose? There is no easy answer. The basic but soluble alum having a deficiency of sulphate ion would theoretically give the amount of alumina desired with a minimum of sulphate ion and, therefore, the ionization would be optimum. On the other hand, there might be a deficiency of acid which, as seen in reaction no. 4, decreases the ionization of alum. Furthermore, it has been shown that aluminum hydrate may be actually harmful to sizing. Certainly a lot of precipitated aluminum hydrate added as a filler would decrease sizing. Therefore, an acid alum may be preferred to a basic one.

Mills at the present time are quite interested in the use of acid along with alum. It has been found that the combination is not only cheaper but in some instances gives better sizing, lower acidity paper, and sometimes stronger paper. Mills have experimented with various mixtures. A typical one would be the use of 700 lb. of alum plus 80 lb. of 66° sulphuric acid to replace 1000 lb. of regular alum. Another mill has used for years a mixture equivalent to 80 lb. of dry alum and 20 lb. of 66° Baumé sulphuric acid. This is not a recommendation for such a system, but rather a suggestion. The use of such an alum must be done with care. Although it is done frequently, it is not yet generally recommended that sulphuric be added independently of the alum since there is too much danger of exorbitant addition with low pH and corrosive conditions being obtained. Alum is a buffering salt, and it is almost impossible to get the pH below 3.8 or 3.9.

A large board mill in the east does use sulphuric acid to replace part of their alum requirements, using 1 lb. of alum to 1 lb. of size (fortified) and then controlling the pH with direct addition of 66° Baumé sulphuric. This results in substantial savings, a higher pH sheet with better aging properties, and more uniform product. They would not suggest installation of this system unless a mill were equipped to handle and service electronic and pneumatic instruments which are required for handling acid.

The complication of the chemistry can be visualized by some study of the following consideration:

Assume a papermaking slurry to which size, and then sufficient alum to reduce the pH to 4.5 have been added. The pH can quite easily be changed by adding an entirely neutral material. The addition of neutral sodium sulphate will cause an increase in the pH of the pulp slurry and an increase in the acidity of the paper made therefrom.

Another but a very surprising reaction is that alum added to distilled water will lower the pH drastically. Alum added to impure water, such as a solution of sodium sulphate, will not lower the pH to anywhere near the same extent.

These and many other similar anomalies are the reason that it is dangerous to oversimplify the use of alum, and preferable to make careful and controlled mill experiments under the conditions pertaining in any particular mill. The alum that all papermakers use may be optimum for a particular mill, but it may not be optimum for all mills.

Empire State (Central District)

The Central District of Empire State TAPPI met at 7:00 p.m., January 7, for its monthly dinner meeting. There were 89 in attendance.

Seated at the head table were F. G. Sommerville, chairman, Empire State TAPPI; Harry Gray, past-chairman, Central New York District; Edwin Jahn, associate dean, New York State College of Forestry; Barbara H. Wortley, secretary; F. W. O'Neil, chairman; Durwood Geffken, vice chairman; and Henry Perry, guest speaker.

Mr. O'Neil introduced those seated at the head table and then turned the meeting over to Mr. Geffken.

S. E. Church, Jr., College of Forestry, State University of New York; H. J. Perry, Waste Paper Utilization Council; Mrs. B. H. Wortley, Solvay Process Div.; F. W. O'Neil, College of Forestry, State University of New York; and D. B. Geffken, Oswego Falls Corp.

Mr. Geffken introduced the speaker for the evening, Henry J. Perry, director of the Waste Paper Utilization Council.

Mr. Perry spoke on the make-up of the Waste Paper Utilization Council, the problems they encounter now as compared with a few years ago, and their solutions to many pressing problems. It was an informative talk and enjoyed by all.

Empire State (Eastern District)

The Dec. 16, 1954 meeting of the Empire State Eastern District was held at Glens Falls Country Club with 72 members present.

The meeting was called to order at 8:30 p.m. by Vice-Chairman Earl Johnson.

Ralph Prince was introduced and expressed his regrets that C. N. Hagar, one of the District past-chairmen, will soon be leaving the area to take a position with Westminster Paper Co. in Vancouver.

Vincent Long, program chairman, introduced R. G. Macdonald, Secretary of National TAPPI. Mr. Macdonald spoke on the suggestion system as a growing trend in employee management cooperation. He also acted as moderator and introduced the speakers of the evening: Allen A. Lowe of the Sandy Hill Iron and Brass Works, who spoke on "Flat Diaphragm Screens," and Harry Schenk of Magnus Metals Co., who spoke on "Screens and Screening Problems."

The talks were followed by an open question and discussion period, and the meeting was adjourned at 10:10 p.m. with the January meeting scheduled for Milfranks on Jan. 21, 1955.

Richard J. Collins, *Secretary*

Flat Screens

Allen A. Lowe

This paper is to be about flat diaphragm screens. The definition of Karl Lindgren, a leading Swedish paper machinery engineer, speaking before the Food and Agriculture Organization of the United Nations, corresponds with my thinking. He speaks of them as being those screens which operate at 200 to 500 vibrations per min. and are generally equipped with slotted screen plates.

The paper proposes to be descriptive, informative, and exploratory. The controversial aspects of pulp treatment after

Allen A. Lowe, Sandy Hill Iron & Brass Works, Hudson Falls, N. Y.

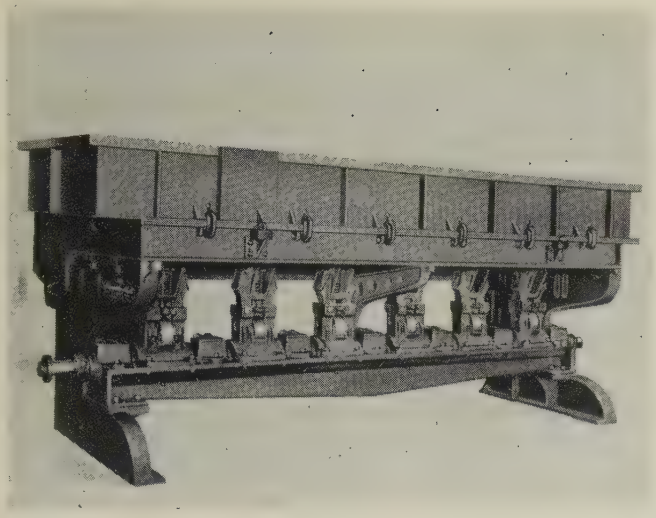

Fig. 1

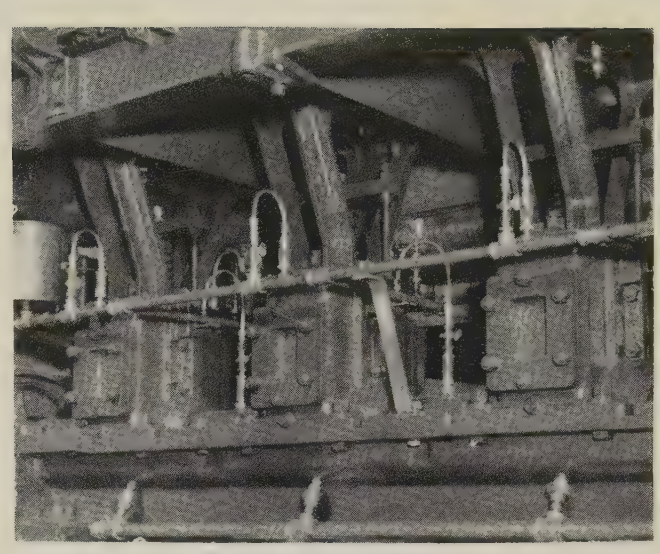

Fig. 3

cooking, grinding, or refining and after that part of pulp purification, which we call bleaching, are not to be considered. I propose to describe a flat screen structurally, tell how it works, and as far as I understand it, why. The combinations of the basic unit for screening large tonnages will be described.

Variants in the operation of the basic unit and the effects on capacity and dirt count will be explored. With the permission of Erik Ekholm, vice-president of the Puget Sound Pulp & Timber Co., I am reproducing a group of charts which are definitive analysis of what happens when certain aspects of flat screen operation are varied.

There is being done some exploratory work on the design of flat screens and, insofar as is possible, the partially achieved results will be described.

Here is a flat screen (Figs. 1 and 2). It happens to be a ten-plate flat screen. It contains five of the basic units. All flat screen systems of any number of plates are multiples of two plate units.

The plates A are carried in the vat. They are actually mounted on cross members C and D. The cross members D seat tightly on the diaphragm B and the cross-hatched area is the diaphragm chamber. For the unit to function the diaphragm chamber must be full. This (Fig. 3) transmits the pulsation from the shaft, cam, and pitman through the diaphragm to the plates and through the slots. The purpose of the vibration is to prevent matting of the fibers on top of the plates. One trouble to look for if flat screens are not screening properly is that the deep cross members are not firmly seated on the diaphragms.

With the same stock and the same slots in the plates the gallonage which passes any basic unit of two plates is determined by the difference in elevation between level of stock E in the cross section and level of the dam G and F. Mr. Ekholm shows, and it is common knowledge in the trade, that the lower point F is, the more gallons will pass. This is a generality which is hedged about by if's and but's and the principal of these are first, if the dam is lowered so far that the accepted stock runs over it faster than it will go through the slots, the pulsation is not transmitted to the top of the plates and they cease to function. Secondly, as Mr. Ekholm shows, the increase of gallons tends to increase passage of dirt and shives and this has to be taken into consideration.

The U-tube formed by the design of the spout leading from the diaphragm chamber to the dam has been proved empirically to be a necessary part of the proper function. Screens, as to this spout and flow box, have been built so that the bottom of the spout was at the level of the diaphragm, and the function of the basic unit was limited. Currently the sectional area of the spout for each two-plate basic unit is spoken of as 60 sq. in. Current experimentation and design may lead to this area being increased.

This leads to what a multiple of these two plate units does. First, it gives a satisfactory fiber classification and secondly, it floats off the dirt. Currently, there is need for the introduction of thinning water through a line of from 24 to 32 plates. Good screening consistency is around $^3/_{10}$ to $^1/_2$ of 1%. This relates to current design of low vibratory flat screens. On screens of improved design preliminary work has indicated that satisfactory fiber classification and dirt removal can take place at one to one and one-half per cent. This consistency is as tested in the accepted stock passages.

Here (Fig. 4) is a conventional arrangement of a number of sixteen plate screens. This is for whole pulp mill screening. There are shown four primary screens in two lines, two secondary screens in one line, and a tailer. It is not unusual to take the accepts from both primaries and secondaries into

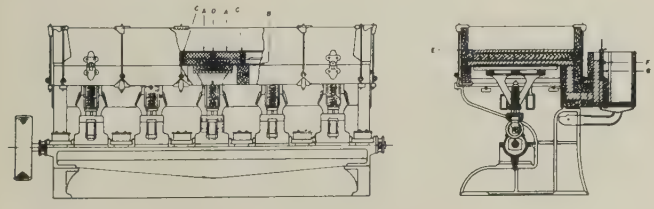

Fig. 2

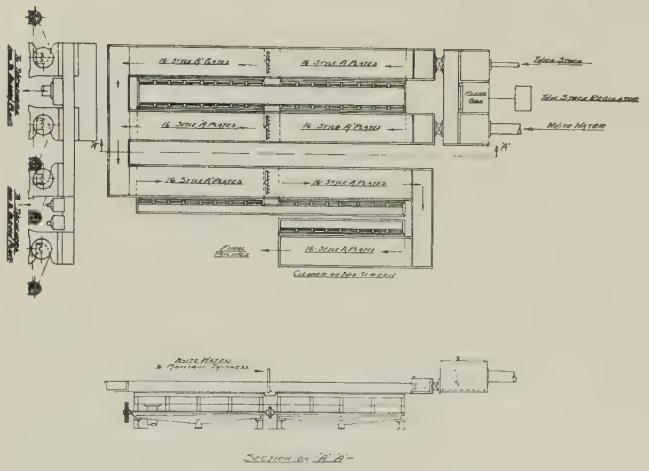

Fig. 4

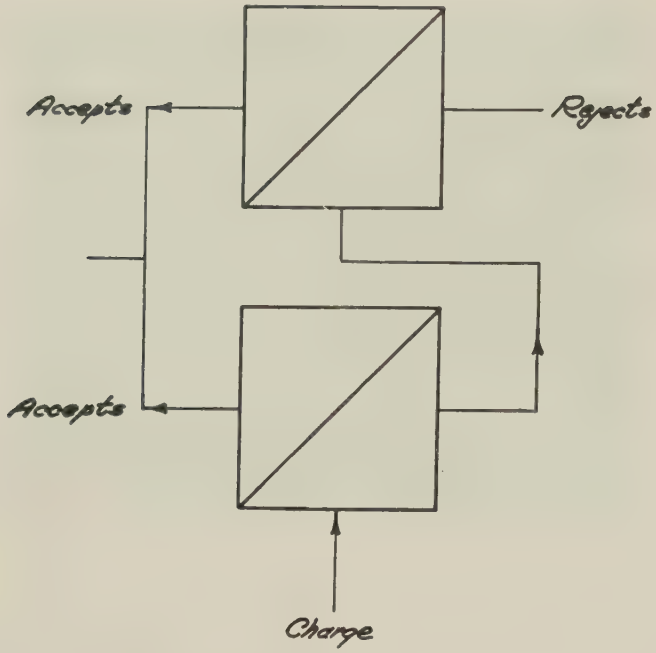

Fig. 5

the same chest. Other disposition is made of the accepts from the tailers. For good screening on flat screens both the primaries and secondaries should be tailed as generously as the whole scheme permits.

Here (Fig. 5) is shown in diagram this system of screening. The accepts from both primary and secondary lines are mixed for further use or treatment.

Here (Fig. 6) is shown a diagram where the accepts from the secondaries are taken back to the primaries, and only the accepts from the primaries taken for use or further treatment. Wide publicity has been given this scheme by a visitor to our Continent, Borje Steenberg. I do not exclude the possibility that some North American pulp mill operators may have worked out independently essentially like schemes. The scheme seems to be justified on the basis that the accepts from the primaries are usually cleaner and freer from shives than secondary accepts.

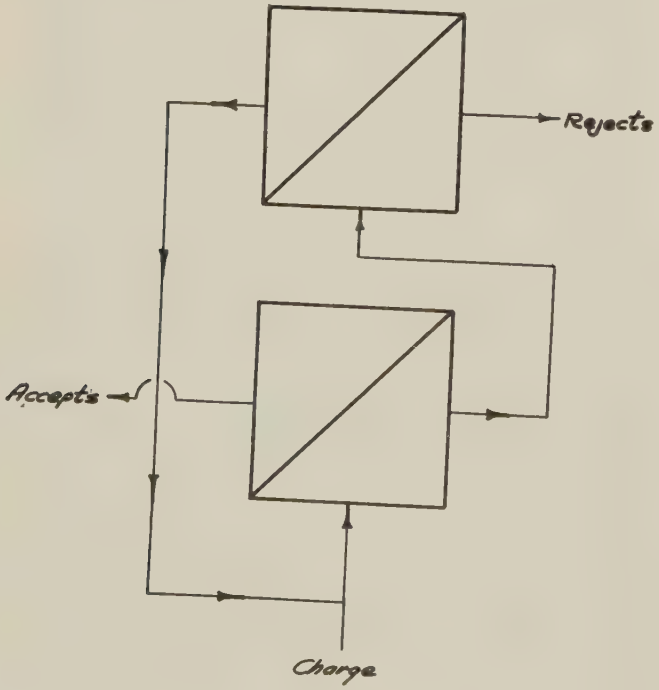

Fig. 6

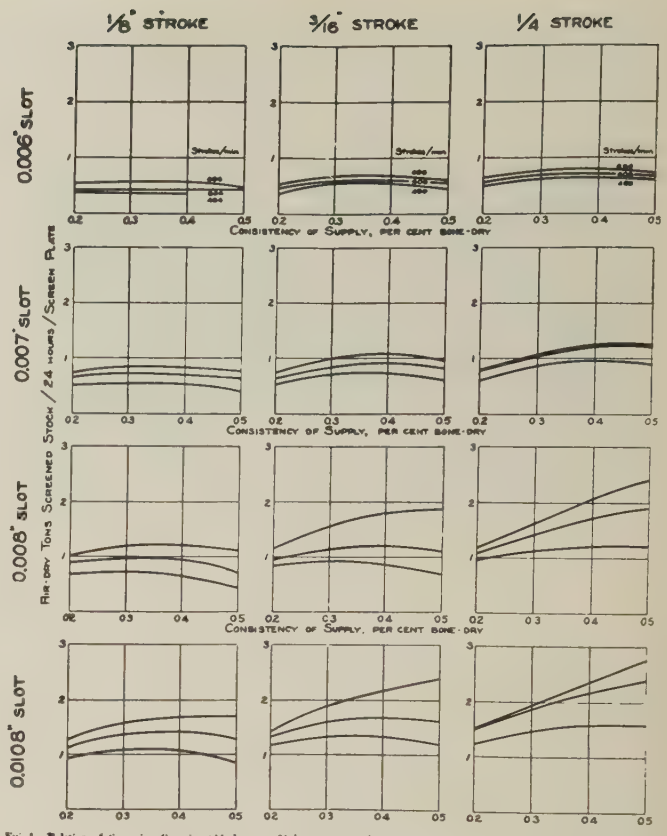

Fig. 1. Relation of Screening Capacity (Air-dry tons 24 hours screen plate) to Length of Stroke, Width of Slots, Number of Strokes per Minute and Consistency.

Fig. 7

After variants in the arrangement of basic units come variants in operation of the screens. Included here would be frequency of pulsation or vibration, length of throw, slot sizes, level of dam, and consistency.

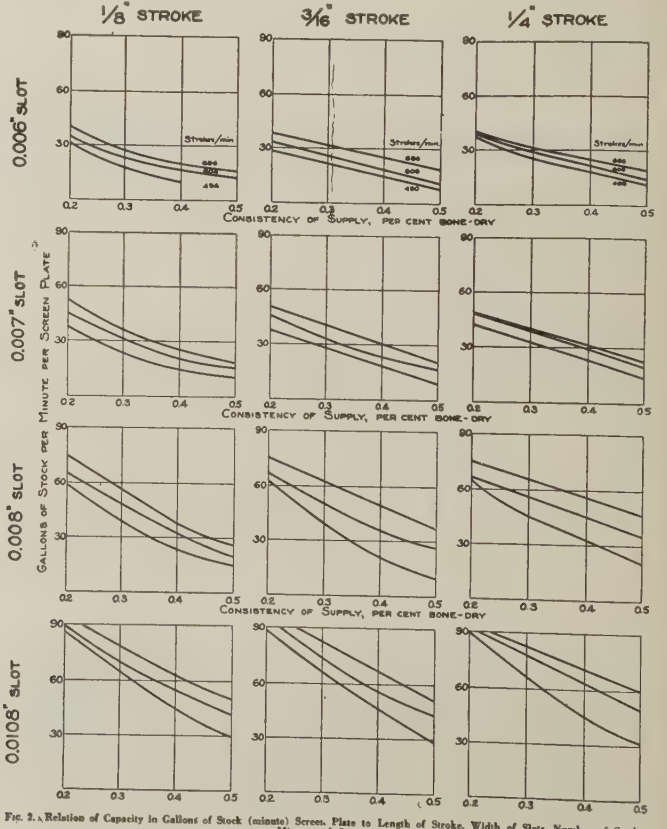

Fig. 2. Relation of Capacity in Gallons of Stock (minute) Screen Plate to Length of Stroke, Width of Slots, Number of Strokes per Minute and Consistency.

Fig. 8

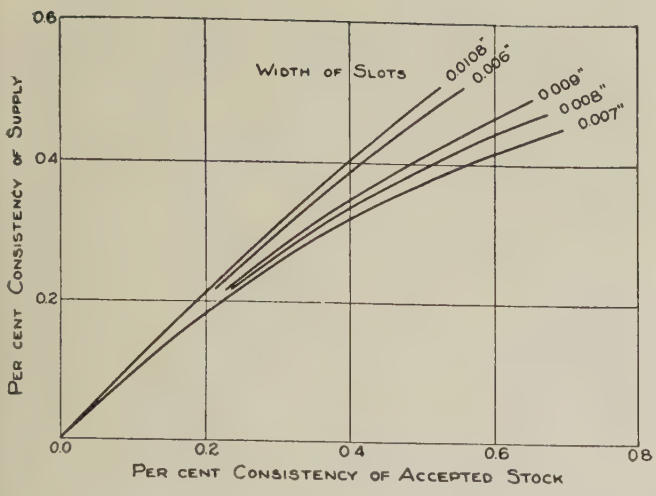

Fig. 9

Mr. Ekholm has permitted me to show the curves developed by him and published in *The Paper Mill and Wood Pulp News* Dec. 30, 1939. The whole article is entitled "Some Practical Observations on Flat Screen Operation." For those who have flat screens to operate and wish to get the best from them the whole article is worthy of study.

Some conclusions as set forth by Mr. Ekholm are as follows: The selection from the whole article is mine. (1) The more dirt supplied the screens the dirtier the accepts, but since they are the last and perhaps the cheapest means of removing dirt they deserve our careful attention. (2) The

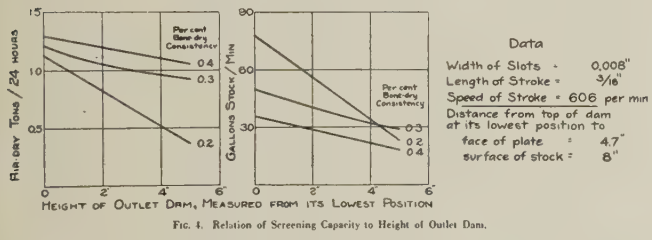
Air dry Tons / 24 hours
Gallons Stock / Min
Per cent Bone dry Consistency
Height of Outlet Dam, Measured from its Lowest Position
Data
Width of Slots = 0.008"
Length of Stroke = 3/16"
Speed of Stroke = 606 per min
Distance from top of dam at its lowest position to
face of plate = 4.7"
surface of stock = 8"

Fig. 4. Relation of Screening Capacity to Height of Outlet Dam.

Fig. 10

curves (Fig. 7) show that when the stock is too thin, the screen must handle so large a volume that the capacity decreases. At the other extreme when the stock is too heavy the fibers mat over the slots and the capacity is diminished. (3) Figure 8 serves the purpose of showing the gallonage to be handled by pumps, deckers, and the like. Gallonage does not follow calculations from Fig. 7. The consistency of the screened stock does not coincide with the consistency of supply. (4) The curves (Fig. 9) (showing relation between charge and accept consistencies) for any particular set of conditions may be either to the left or right of those shown. They may even exchange positions. (5) If the outlet dam is raised (Fig. 10), the head, the force pulling the stock through the screens, is decreased and the capacity of the screen drops.

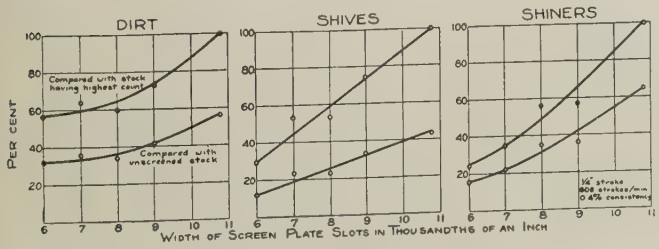

Fig. 11

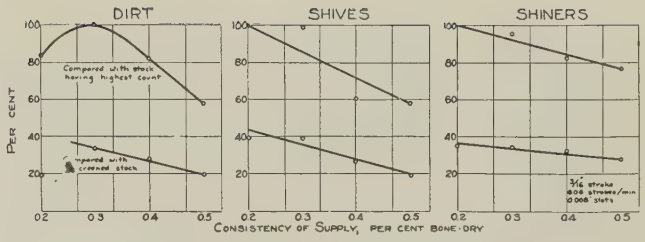

Fig. 12

I would add that, roughly, you can reverse this, and say that the lower the dam the more the gallons to the point where no more gallons will pass the plates. Then you must back up and keep the diaphragm chamber full. As the outlet dam is lowered, however, in the narrow cuts, especially while screening stock containing a high percentage of tailings, the slots are apt to plug so that the net result may be a decrease in capacity. (6) As the capacity (volumetric—meaning gallons rather than tons) increases, the dirt count increases; as the volumetric capacity decreases, the dirt count decreases. (7) The ratio of the screened count to the unscreened count is the per cent of the total dirt which passed through the screen. The lower curve of Fig. 11 is a plot of this ratio. It clearly demonstrates that one never gets 100% efficiency in screening, only a percentage removal which varies with the impurities furnished the plate. (8) Figure 12 bears out the supposition that the velocity of the stock affects the quantity of dirt carried through the slots. (9) Here again (Fig. 13), increasing the velocity of stock through the slots increases the amount of dirt carried through.

The treatment of stock after, and in the course of purification, demands fiber classification and dirt removal. Fiber

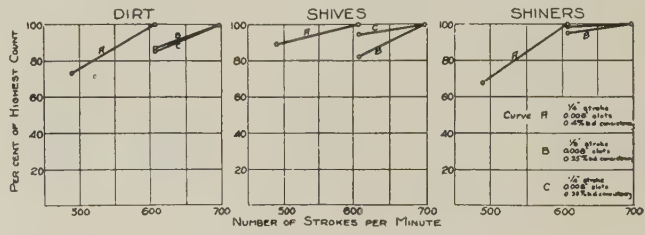

Fig. 13

classification of a great deal of pulp is still most satisfactorily done on flat screens, and substantial dirt removal affected at the same time. What I may call, for lack of a more exact name, the Steenberg scheme, based on the theory of probability, will doubtless be adopted in many screening operations to great advantage.

I have hoped here only to explain the basic facts about how a flat screen functions and what its variants may be expected to accomplish. This may recall to you principles through which you can use to better advantage flat screens either existing or projected.

I have said little save: here is a flat screen; it works this way; it will classify fibers and remove dirt to an efficiency based on how you handle its variants. Its efficiency will also improve with good maintenance and intelligent operation from day to day. On paper machines flat screens reduce formation problems.

Currently we have in mind changes in design. Preliminary investigations have shown us that screening through slots at least as fine as 12 thousandths can be done at consistencies of 1% and even 1½%. Sizes of thickeners, pipe lines, and pumps will be greatly reduced. A large percentage of pulp now made passes over flat screens and we look for improvement in the basic value to the trade of flat screens.

Empire State (Northern District)

The Northern District of Empire State TAPPI held its December meeting on Dec. 9, 1954, at the Hotel Woodruff in Watertown, N. Y. Forty members were present. The program consisted of a talk by Alfred Wagner, instrument engineer, Newton Falls Paper Mill, "The Use of Instruments at Newton Falls."

Mr. Wagner showed instrument charts indicating utilization of instruments at various points. The operations involved include deinking, repulping, washing, bleaching, paper machine operation, and coating. Although the Newton Falls mill employs many instruments, Mr. Wagner discussed three areas of general interest. namely, basis weight, moisture content, and pH.

Basis weight is measured using a beta gage instrument in which the amount of rays which pass through the sheet is proportional to the weight of the paper. Indications are that this instrument application offers possibility toward ultimate control of the operation.

Moisture content is measured by changes in the dielectric properties of the sheet.

The pH controller has electrodes which are immersed in the white water near the wire and operates a pneumatic controller on alum supply. High pH tends to increase wire life.

Results obtained to date using the above instruments indicate a close relationship between the three variables discussed, and the use of the instruments has resulted in obtaining accurate and valuable data.

ELIZABETH L. CASE, *Secretary*

Empire State (Metropolitan District)

On Nov. 9, 1954, about 50 members of the Metropolitan District, Empire State Section of TAPPI made a plant visit to the paper mill and box shop of the Gibraltar Corrugated Paper Co., Inc. in North Bergen, N. J.

Following the plant visit the regular dinner meeting was held at Fraunces Tavern in New York City. About 60 people were at the dinner to hear Joseph Theriault of the Robert Gair Co., Inc. speak on "An Approach to Statistical Quality Control in a Board Mill." Mr. Theriault's talk is printed below.

An Approach to Statistical Quality Control in a Board Mill

Joseph F. Theriault

IN THESE times of a quality conscious buyer's market there is little need for anyone to point out the necessity for some sort of product quality control. The mere fact that the salesman can point with pride to an efficient quality program may be the psychological "clincher" to close an order and is perhaps enough to justify the existence of the system.

Since Shewart's successful application of statistical methods in the analysis of data collected by inspecting the quality of such products produced in the piece-parts industries we have been swamped by statistical quality control. One only needs to scan the book lists received in the morning mail to be convinced of its popular appeal. (I don't suppose there is anyone here who hasn't been advised by his superior at some time or other to, "see what there is in this thing we can use.")

Before we get into this discussion, however, it might be well to take stock of the successes attributed to the application of statistical quality control methods. The magazines and literature are filled with articles extolling its virtue in connection with the quality of electric light bulbs, rivets, automotive parts, and the like. In these instances it will be noted that machines are producing pieces which may be sampled at will. If the sample fails to meet some simple test as the "go or no-go" gage used in many instances by the machine trade industries the machine may be shut down to make the necessary adjustments that will eliminate the production of defective pieces and the process is on its way again.

In the paper mill the situation is a bit different. If you happen to have been one of those who has had his "little talk" with the boss and are fortunate enough to be employed in a mill integrated with a box shop you probably realize how lucky you are. The press room is made to order for the application of the piece-parts methods. The production may be sampled at will. The sheet may be examined for defects and an evaluation of their severity against some standard may be made in order to determine the appropriate action to prevent the continued production of defective material. If you have been asked to institute a statistical quality control program and have not already done so this is a good place to start.

The papers published by Brainerd Sooy should be of considerable help in this instance.

The pressman, however, will constantly blame many of his troubles on "that board that he gets from the mill" and eventually you will be called on to investigate this source of trouble. Or you may not be fortunate enough to have a box shop in which you can get your feet on the ground and must set up a system of statistical quality control in the mill itself.

Let us then suppose that you are met with this problem. Where will you begin? Since we are all in the "same boat" I would like to advance a few suggestions.

At the very start you are at the mercy of your testing equipment. It will pay off, in many instances, to start your control system here. Some scheme of testing and recording the accuracy of all testing equipment periodically is a "must" in the collection of dependable data that will eventually be analyzed. Many lengthy accumulations of data collected at considerable expense have been found to be worthless on account of some simple aberration in the testing equipment. It may be even that you will be so lucky as to pay off the entire cost of an inspection by finding a 5% error in basis weight scale as one of our men did in such a check.

Be sure that your inspectors are thoroughly acquainted with the operation of the testing equipment. In many instances this initial caution will be sufficient to insure the collection of satisfactory data. But in others a periodic recheck of their methods will be necessary to insure the continued adherence to the standard procedures. At the risk of seeming too simple I would like to call attention to the habit of cutting samples double thick particularly in the box boards mills. This usually results in cutting one of the samples out of a square. A square foot sample $1/4$ in. skewed on one edge will cause an error of 1.05% in the weight as reported which in turn not only invalidates the data but causes unnecessary changes on the machine. The investigation of possible sources of error in testing equipment and its use should never be considered trivial in a quality control system statistically operated or otherwise.

At this time it might be worth while to emphasize the fact that one should, if possible, employ a test to determine the fitness of the product in terms of the customer's requirements rather than testing for testing's sake. The sales department should be helpful in guiding the control department to the proper tests.

Once the equipment is in order and the operators thoroughly versed in its operation, the accumulation of data can be started. A study of the immediate as well as the future use of these data should be made before any quantity of data is accumulated. A well-planned data sheet will save hours of needless copying at some future date. I would like to illustrate this point. In the past we have in many instances recorded the data in a vertical manner.

JOSEPH F. THERIAULT, Robert Gair Co., Uncasville, Conn.

Reel	Weight	Caliper
1 F	96	020
FC	97	021
BC	97	022
B	96	020
2 F	97	022
FC	97	021
BC	98	020
B	95	020
3 F	96	022
FC	98	022

This method does not lend itself to future statistical study. May I suggest that it might be helpful to record the data in this fashion.

Reel	Weight				Caliper			
	F	FC	BC	B	F	FC	BC	B
1	96	97	97	96	020	021	022	022
2	97	97	98	95	022	021	020	020
3	96	98	97	96	022	022	020	020

In other words be sure that if the data are to be statistically analyzed that they are in a workable form. In many instances part of the calculations may be completed by the inspectors themselves at the time the data are collected by inserting a column for simple averages and ranges on the record sheets.

When the data begin to come in a good deal of your time as well as one or two tabulators will be required to determine grand averages and average ranges for the various measurements if the limits of the process capability are to be established by the control chart methods described in any of the books and pamphlets concerning statistical quality control and in particular by the American War Standards. Don't be in too much of a hurry to publish limits and standards. Collect the data. Analyze them as they come in and try out the limits on future production of the same product, but do not publish the limits until you are sure of your ground. It may take a year to accomplish this for all grades. (Be sure to warn your superior of this.)

It is also wise to keep a record of the rejections and complaints in the interim because eventually someone is going to ask "what are we getting out of this scheme for the money we have spent?" It is interesting to note that the piece-parts industry rates the cost of a system at about one tenth the value of the rejects and complaint settlements.

During this time someone "out front" may get "chart happy." As a palliative to his demands it might be well to eventually include a second half to your record sheet upon which a graph of the test results may be plotted with the limits drawn in when you are satisfied that they are well established.

Officers of Western District: front, l. to r.: Ernest F. Andrews, treasurer; George Norton, chairman of Arrangements Committee; James J. Forsythe, chairman; Robert H. Zinsmeister, vice-chairman. Back, l. to r.: Gordon K. Stocin, chairman of Membership Committee; H. Elroy Lindeberg, secretary; Oscar E. Anderson, Jr., chairman of Publicity Committee; Harry B. Hulse, vice-chairman of Program Committee; and Charles W. Raleigh, chairman of Attendance Committee

quality mindedness among the crews. A sheet of insulating-sound proofing board with the grand average and calculated limits drawn in may be used as a large-scale graph by inserting black knobs in the holes at the relative positions of the test averages.

To supplement the whole program the administrator should continually be on the lookout for automatic devices to control and record the fluctuation in the property being inspected. Many devices will be found on the market for measuring and controlling weight, moisture, and caliper as well as consistency and perhaps freeness. You should be on the alert to the possibilities of their application at your mill as they may help or even eliminate some of the tedious testing procedures.

You may now ask this question? Now that I have spent a year of my time and that at one or two tabulators, what have I got out of this business that I wouldn't get out of the old methods of tabulating data usually employed?

I believe you now know.

1. The process capability of your machines and the limits of the normal variability due to chance fluctuations that you did not get from a tabulation of results.
2. These limits may be used to set up reject and acceptance limits for future productions that are real.
3. These limits may be used to lead the way for improvements in machine changes that will improve the quality of the production.

Reel	Weight						Caliper						Weight			Caliper		
	F	FC	BC	B	Av.	Ran	F	FC	BC	B	Av.	Ran	95	96	97	19	20	21
1	96	97	97	96	96.5	1	020	021	022	020	0208	2						
2	97	97	98	95	96.8	3	022	021	020	020	0208	2		(Chart results here)				
3	96	98	97	96	96.8	2	022	022	020	020	021	2						

The actual plotting may eventually be made by the inspector as he determines the average and range of the various tests. In this way production crews get acquainted with a graph in a painless manner. But do not give up the tabulation of data because a chart of averages and ranges will eliminate the variations of the individul readings which are the basic guides to the machine and backtender in making changes during the production of an order. You may find it worth while to post large-scale graphs of the various tests as the program goes on. This will stimulate interest among the workmen and generate

4. These limits may be useful in future customer relationships in settling complaints and establishment of specifications. In fact it may be necessary for you to tell a salesman that "we just can't make this board."
5. The graphic representation will serve to make the workman quality conscious.
6. The graphic study will eliminate unnecessary changes; in fact just the other day I heard this statement. Quality control by statistical methods may alarm us in the variation of the quality of the material we are thinking we are making,

but by the elimination of unnecessary changes we may be able to make a better product than we actually are.

December Meeting

About 50 members were present at the Dec. 14, 1954, meeting of the Metropolitan District, Empire State Section of TAPPI, held at Fraunces Tavern in New York City.

Victor Bird of the Research Division of the American Cyanamid Co. at Stamford, Conn., presented a talk entitled "Let's Look and See," in which he described some applications of the microscope to the paper industry. Mr. Bird substituted for A. F. Kirkpatrick of the American Cyanamid Co. who was unable to attend the meeting.

Mr. Bird illustrated his talk with a number of microphotographs. He explained how the use of the microscope aided in solving some of their problems. He also discussed the various techniques used for preparing and mounting paper samples. His talk was followed by an interesting question and answer period.

L. E. Georgevits, *Publicity Chairman*

Kalamazoo Valley

The following paper was presented at the December 2 meeting of the Kalamazoo Valley Section.

Development and Use of the LTF Pick Tester

Gordon C. Wheeler

This paper consists of three parts: a review of previously published concepts, correlation of LTF pick tester results to industrial experience, and current work.

On the printing press, the splitting ink film dynamically loads the paper. Several paper and ink properties are involved. The paper's ultimate tensile strength and elongation perpendicular to its surface and also its ability to absorb ink vehicle all contribute to its pick resistance. The ink film's resistance to rupture at a given splitting rate, the change that this resistance undergoes when the ink is in contact with paper, and also its elongation before rupture all help determine whether rupture occurs within the paper or in the ink film.

These properties are important because of the nature of the printing impression. Figure 1 shows the printing impression diagrammatically.

Duration of contact between the paper and blanket (a to d) is roughly one hundredth of a second. During this time pressure is being applied, so absorption of ink vehicle is probably promoted by both the capillarity of the paper and the applied pressure.

The force required to rupture an ink film at a given rate of loading is influenced by the quantity of vehicle removed by absorption into the paper. Also the thinner the film, the greater the force developed. This has been illustrated on a paper coated with dissimilar coatings on the two sides. One side had a very absorbent coating while the other side was much less absorbent. Body stock failure occurred on the LTF pick tester with test inks 3 and 5 for the very absorbent and less absorbent sides, respectively. Because of the nature of the LTF pick test it is very unlikely that two sides of a piece of paper would show differences in body stock pick resistance for any reason except a change in ink tack during contact.

The force required to rupture an ink film is dependent on the rate of loading. On a cylinder press, this rate is dependent on the speed of the press V (in Fig. 1), the distance bd from the plane of the cylinder axes to the rupture line, and the elongation of the paper normal to its surface. The paper acts as a resilient member cushioning the application of load to the ink film.

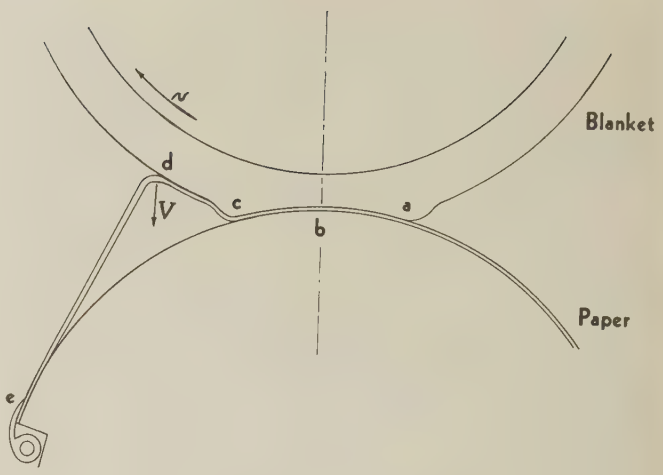

Fig. 1. Diagram of impression

This description of the printing impression indicates which paper properties should contribute to pick resistance. Tensile strength normal to the paper surface determines whether rupture will occur in the ink film or in the paper under the conditions of ink tack and rate of loading at the moment of rupture. Any change in ink tack during the impression due to vehicle absorption by the paper will influence the pull of the ink at rupture. Elongation normal to the surface of the paper will influence the rate at which the ink film is split and thus the force developed.

The problem of pick testing involves the measurement and proper weighing of three paper properties: tensile strength, elongation, and ink vehicle absorptivity. The use of test methods involving printing techniques is an attempt to do all this at once.

To ensure proper weighing of these properties, a printing test should include contact periods, pressures, and separation velocities between printing form and paper that are comparable to those to which the paper will be subjected when printed. Also the test inks should have rheological properties similar to those of printing inks.

The LTF pick tester was designed to approximate contact periods, pressures, and separation velocities encountered on

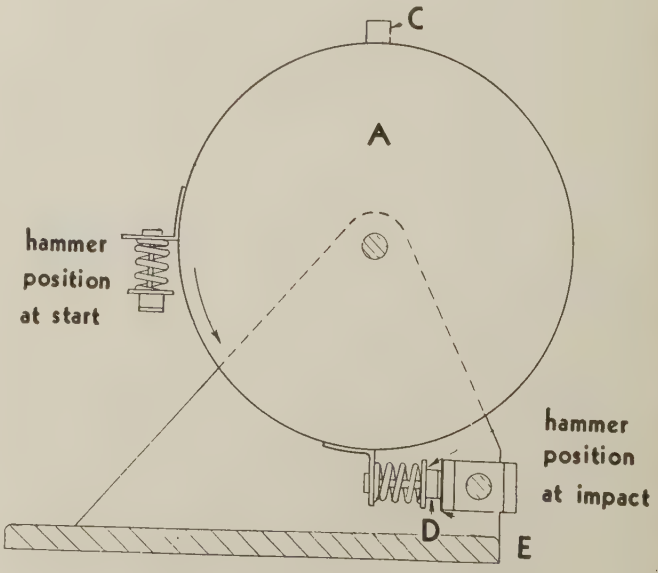

Fig. 2. Diagram of pick tester

Gordon C. Wheeler, Assistant Supervisor, Paper and Ink, Lithographic Technical Foundation, Chicago, Ill.

commercial offset presses. Its design is shown in Fig. 2. The flywheel A is unbalanced by weight C and the weight of the spring assembly. This unbalance provides impact velocity when the inked hammer D, which is covered with a piece of offset blanket, swings into contact with the paper sample E. On impact, the kinetic energy of the flywheel is stored in the spring, causing it to rebound and carry the hammer back with it. The flywheel moment of inertia and unbalance, modulus of the spring and spring loading, and the distance allowed for the swing are calculated and adjusted to give the desired characteristics of pressure, period of contact, and rate of separation.

A series of tack-graded inks is used with the LTF pick tester, and the number of the least tacky ink picking the paper indicates its pick resistance.

CORRELATION TO INDUSTRIAL EXPERIENCE

Samples of paper have been tested for both printers and papermakers when picking difficulties had been encountered. In some cases both satisfactory and unsatisfactory samples were submitted. In others, only the papers which performed unsatisfactorily were supplied.

The breakdown for the latter group is shown in Table I. The bulk of the inquiries on pick troubles concerned papers of pick strength 2 to 5. The average of the first 33 coated offset papers selected at random was $5^1/_2$, so it is evident that most of the pick troubles we have seen involve below average paper.

Table I. Poor Paper Only

LTF pick strength	*Inquiries*
2	6
3	12
4	6
5	6
6	3
7	1

The breakdown for the group in which both good and bad papers were supplied is given in Table II. In only one case is the LTF pick test the same for both satisfactory and unsatisfactory samples. In this case, both papers blistered on the press, but one was not severe enough to cause rejection of the job. In all other cases, the differences ranged from one to four ink numbers.

Table II. Good and Poor Papers Used on the Same Job
LTF pick strength

Poor sample	*Good sample*
Coated Papers	
2, 3	7
3	4
6	7
3	4
3	3
Uncoated Papers	
6	7

It is also evident from this group that a pick strength that is satisfactory for one printer on a certain job may not be sufficient for another job or printer. Very seldom were we able to see both papers actually being printed, so we have practically no information on ink tack and press speed for the data in these two tables.

As we study increasing numbers of picking problems, it becomes very apparent that attempts to standardize the pick strength requirements for the lithographic industry would be of limited value. The requirements vary so widely, depending on equipment, work, and other circumstances, that few

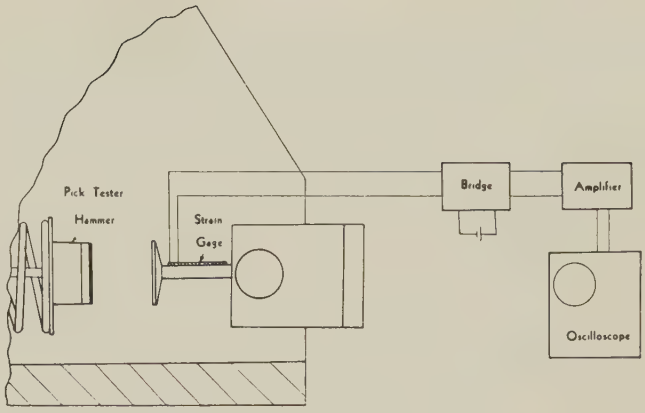

Fig. 3. Strain gage attachment

papers in use today would come up to the most stringent minimums, yet only a very small percentage of the paper sold for offset printing gives picking or related troubles.

This is indicated in Tables I and II. In five cases, a pick strength of 6 was insufficient for the particular job requirements, yet in many cases a pick strength of 4 has been sufficient.

The two cases in Table II where a 6 was insufficient are good examples of the importance of the job and printer. A heavy solid with gloss inks was going on the coated paper. The job was on a large four-color press. Body stock failure occurred with the poorer sheet. This same sheet was running satisfactorily on other jobs having less coverage.

The work on uncoated paper consisted of four-color halftones. The problem encountered was loosening and removal of fibers from the paper surface. This grade as supplied by the manufacturer normally has an LTF pick strength of 7. The lot giving trouble had a pick strength of 6. Apparently the lithographer had set up conditions on his presses for the stronger paper and encountered trouble when the pick strength was reduced.

It appears from these experiences that the conditions under which the paper is printed and the job being run should determine the pick strength requirements. Arbitrary standards would be of little value.

CURRENT WORK

As part of a study on the fundamentals of ink transfer to paper, an attempt is being made to separate the influence of the three paper properties: tensile strength, elongation, and ink vehicle absorptivity. To do this, a strain gage was mounted on the anvil to measure forces developed during the impression. Figure 3 is a diagram illustrating this arrangement. Strain gage output is amplified and recorded by use of a camera mounted on an oscilloscope.

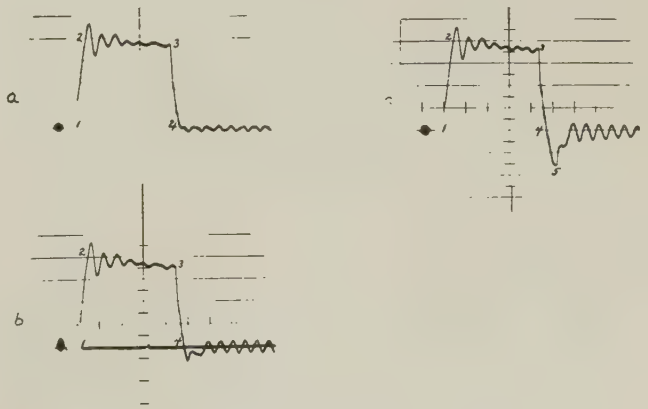

Fig. 4. Stress-time traces (soft ink)

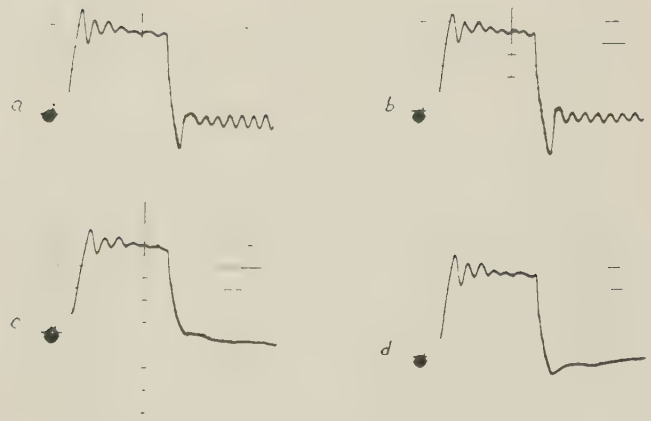

Fig. 5. Stress-time traces (tacky ink)

A few exploratory tests have been conducted. Figure 4 is a series of three tests. (1) the impression without ink or paper, (2) a very soft ink alone, and (3) the same ink with a very absorbent paper.

The horizontal axis is time and the vertical, force. Contact between hammer and anvil occurs at 1, the spring is compressed and released from 2 to 3, separation of hammer and anvil occurs at 4, and maximum pull of the ink occurs at 5 in trace C.

In this particular test, the period of contact between blanket and paper under positive pressure was about 0.013 sec. The amount of force required to rupture the ink film applied to the paper was three times that required to split the ink film when applied to the nonabsorptive metal surface.

The spot to the left of the trace is the dot waiting to be triggered. The gap between it and the start of the trace is determined by the way the oscilloscope triggers.

The peak at point 2 is probably due to the inertia of the hammer head. The slope of the line from 1 to 2 is determined by the velocity of impact. The oscillations both during impression and after separation are probably due to mechanical vibrations.

Figure 5 is a series of tests with a fairly tacky ink. In (1), the ink film is being ruptured without contact to paper. In (2), the same ink is printed on a very tough uncoated cover stock. In this case, the pull of the ink is increased about one third by contact with the paper.

In (3), a very weak chipboard (0.042 in. thick) is being split with the same ink. Elongation of the sample was so great that complete splitting had not taken place in the picture.

In (4), the same ink is applied to a 0.016-in. board. In this case, the great elongation before actual rupture is evident.

These are just exploratory experiments to indicate what might be studied with this technique. It might be possible to determine the relative importance of paper film roughness, ink film thickness, paper elongation, paper absorbency, air entrainment, pressures, separation velocities, and the increase in ink pigment concentration due to vehicle absorption on ink rupture forces. Possibly the relative importance of cavitation, elasticity, viscous flow, and the change in rheological properties with change in pigment concentration in ink during transfer to paper can be determined. Also, a study of tack build-up in ink films with time and its effect on printing and on pick-strength measurement may be of fundamental interest.

January Meeting

The Kalamazoo Valley Section met at the Hotel Harris, Kalamazoo, Mich., on Thursday, Jan. 13, 1955. The meeting was held jointly with the Michigan Division of the American Pulp and Paper Mill Superintendents Association. More than 400 persons attended this Twentieth Annual Get-Together.

During the afternoon the occasion was featured by a reception at Western Michigan College in honor of the speaker of the evening, D. Clark Everest, chairman of the board of the Marathon Corp., Rothschild, Wis., who donated a collection of rare books on papermaking to the college.

James A. Wise, president of the Kalamazoo Paper Co., presided as toastmaster. Brief remarks were made by Harry Hadley of the Gardner Board & Carton Co., Middletown, Ohio, on behalf of the Superintendents' Association and R. G. Macdonald, National secretary of the Technical Association. The principal address was made by Mr. Everest.

A Review and a Preview of the Paper Industry

D. C. Everest

It is, indeed, a pleasure for me to have this opportunity to participate in the program at this "Papermakers Get-Together." To me, coming to Kalamazoo is like an "old homecoming."

While it has been 16 years since I had the opportunity to talk to the Michigan Division of the Superintendents' Association about the paper industry, it has been 55 years since I was employed by the late Frank H. Milham to work for Bryant Paper Co. While I only remained with Bryant for about 3 years, I still think of Kalamazoo as my home town and Bryant as my first love in the paper industry.

Many of the people who were then in the industry in this area have since passed on, but I still have a few friends who were active at that time. Several of the people whom I knew and with whom I was associated have gone on to become important factors in the paper industry in this country and in Canada.

While I never had the advantage of a technical education, I soon foresaw the necessity of having technically trained men in the industry and that the future of the industry would depend on their research and development work.

In 1915 I was quite active in the formation of the Technical Association with such men as Fletcher, Mahler, Bishop, Keenan, and others. Again, in 1919, I did all I could possibly do to further the formation of the Superintendents' Association under the leadership of the late Fred Boyce and his associates. There has recently been much emphasis put on the word "coexistence" and that might well describe the early days of these two associations. Happily, that situation has long since disappeared.

I think none of us ever dreamed how successful would be our efforts in the formation of the two associations. Today the foundation of the entire paper and paperboard industry rests on the members of the two associations so far as the development of products and the manufacture of them are concerned. Much has been done to reduce costs, improve quality, and bring about a more scientific approach to every problem with which we are confronted.

I also wish to commend the engineering and technical staffs of both our equipment manufacturers and our suppliers of machine clothing and raw materials for the contributions they have made to the benefit of the industry. It has been a cooperative effort of development which has paid off for all concerned.

Having been in this industry for 55 years and having gone through some lush times and also some very difficult times, I believe, without any egotism whatever, that I have had the experience necessary to talk on the subject of "A Review and Preview of the Paper Industry." I chose this same subject for a talk before the Chicago Professional Paper Group in 1945, but in the 10 years since that time the paper industry has grown to such an extent that a review of what has happened and a prediction as to what may occur in the future I think is not out of place. In the 1945 speech I said,

D. C. Everest, Marathon Corp., Rothschild, Wis.

"When one undertakes to make a review and a preview of the paper industry at this time, he finds that the review is comparatively easy, but the preview must be based on his knowledge of the industry and his individual analysis of all that has been written on the subject and his own thoughts of things that are to come."

I feel now exactly as I did then and perhaps one sticks his neck out in predicting the future, but it is being done by so many economists and others that I think I am reasonably safe in basing my predictions on my observations of how the industry has reacted to various situations over the past 55 years.

At one time I thought I had developed a formula, or one might call it a "rule of thumb" basis, for predicting the consumption of paper and paperboard in tons. This formula was a million tons of paper and paperboard consumed for each 10 billion dollars of national income. Many things have occurred to upset this formula, but when we have had some semblance of what we might call normal times, it is surprising to see how closely this rule of thumb formula worked out.

In 1900 when I started in the paper business, consumption was about 2,250,000 tons. This covered all grades including paperboard and, at that time, accounted for practically all of the newsprint used in this country. Importations were negligible. At that time there were about 75 million people in this country and the per capita consumption of paper and paperboard was about 58 lb.

By 1917, at the beginning of World War I, consumption per capita had increased to 119 lb., or practically double and the total over-all consumption had reached a little over 6 million tons. This held steady during the 3 years of government control, then continued to increase until the year of 1929 when it reached an all-time high of 13.4 million tons with a per capita consumption of 220 lb.

This record stood until 1936 when we consumed 14.7 million tons with a per capita consumption of 229 lb. Peak consumption was again reached in 1941 and for the following 4 years continued at about the same total tonnage rate due to government control of raw materials. The consumption per capita during this period varied from 280 to 285 lb.

Following the cessation of the war and controls, consumption per capita and total over-all tonnage per year increased by leaps and bounds until today we are consuming approximately 400 lb. per person and the total over-all tonnage is in excess of 32 million tons. I doubt if any other basic industry has increased the use of its products at the same percentage rate in 55 years—from 2.25 to 32 million tons. Some industries which have been established since 1900 may have done so.

In a recent meeting of the United States Pulp Producers Association, I also discussed what has happened in the chemical pulp industry and in the waste paper industry during the past 20 years. We should all be interested in what has happened in our raw material supply. There have been too many changes in the last 2 or 3 years to warrant depending on the historical data of the past in projecting the possibilities of any new expansion program. In the pulp producers' meeting talk I said,

"Anyone who maintains an optimistic outlook at all times regardless of conditions, and I may say that conditions change more rapidly today than they did even a few years ago, is simply a 'Pollyanna.' If an industry or a segment of an industry is to be successful, the people who are engaged in it cannot be floating around in the clouds or picking daisies. They cannot take over-all industrial indexes as a guide to their own most remunerative future action. This is an *era of analysis*, and a *mighty careful analysis* coupled with all the imagination and perception one can muster, if he is to consider expansion program or a revamping of old facilities."

I also said,

"With all that is going on in the various research departments of government and private industrial laboratories today, I am a bit confused as to the type of pulp mill I would build at this time and the species of wood I would endeavor to supply it with. It would be difficult to determine whether it would operate on soft or hardwoods or the percentage of each. What would look like an ideal plan at any particular time might be obsolete before the mill could be completed. Location and many other features including wood supply may be extremely important in a long-range appraisal of any new development.

"Let us examine the situation on an over-all basis as it appears today.

"As we approach the end of the greatest expansion cycle in the long history of the pulp and paper industry, it is an appropriate time to look at the record and consider the outlook.

"The domestic wood pulp industry has tripled its productive capacity in the past 20 years. Since the end of World War II, pulp capacity in the United States has increased at an average rate of a million tons a year—from 12 million tons to about 22 millions tons. About half of this 10-million ton capacity increase is in 32 new mills built since 1946; the other half has resulted from improvements and additions to existing facilities.

"Ten million tons of new postwar capacity represents a lot of pulp. It is, for example, more pulp than Canada has ever produced in any single calendar year. It is more pulp, by almost 50%, than the entire Scandinavian industry produced in its best postwar year. And it is more pulp, by 52%, than the United States produced in its most favorable prewar year.

"We used to be concerned about the impact of pulp imports from Europe upon our domestic economy—and quite properly so. In their peak year, however, imports from Europe totaled less than $1\frac{3}{4}$ million tons—only about one-sixth of the new domestic capacity installed since the end of World War II. This arithmetic may help to place in proper perspective the significance of this postwar growth.

"The rate of expansion of productive capacity has slowed down although there are several large mills in course of construction both in the United States and Canada. Work of rehabilitation of existing facilities, of course, still goes on. Personally, I think this slowing down is a good thing. It will afford domestic pulp and paper producers an opportunity to review their current position, consolidate their gains, and give more studied attention to the future.

EFFECTS OF EXPANSION

"An expansion cycle of the magnitude of the one that we have just been through, obviously, has solved many problems for many people.

"In combination with an expansion of somewhat lesser magnitude in Canada, it has, for the time being, eliminated fear of pulp and paper shortages in North America. It has reduced United States' dependence upon overseas' fiber supply sources. It has guaranteed long-range continental self-sufficiency in fiber and fiber products. It has resulted in greater product diversification. It has furthered our national security by solving problems of those concerned with matters of national defense. In these respects, expansion has accomplished what it was intended to accomplish.

"But expansion also creates problems—technical, economic, and social. Increased production will result in increased requirements of wood, water, power, and chemicals; individually and collectively, we must devote more attention to the short- and long-range problems incident to raw material procurement. Expansion will also increase our personnel requirements, both at the operating and executive level, and force us to pay more attention to problems of recruitment, training, and employee relations.

"It will result in bigger and better pollution problems that will cry for intelligent solution in the public interest. It will result in more aggressive competition, and necessitate a better

understanding of market behavior and of the arithmetic of 'break-even' costs. It will necessitate more intensive study of the possibility of further end-product and by-product development. And it will require more careful market research to insure that any new expansion is realistically geared to prospective requirements for the future, and not blindly geared to the growth rate of the recent past.

"To the consideration of this last problem, I'd like to contribute a few thoughts.

THE GROWTH RATE

"Two factors determine the rate of growth for wood pulp: (1) the growth rate for the end products of fiber, and (2) the relative importance of wood pulp in the over-all fiber furnish of these end products.

"Let's examine these factors as they have operated in our pulp and paper economy in the recent past, and as they may be expected to operate in the period ahead.

End-Product Requirements

"In the postwar period (1945–1953), domestic consumption of paper and paperboard has increased 11.5 million tons or 59%. Of this total increase, only one-fourth was attributable to increased population; the remaining three-fourths was attributable to increased per capita consumption. If, since 1946, we had depended upon population increases alone to generate new markets, our pulp and paper consumption last year, instead of totaling 31.25 million tons, would have totaled only 22.4 million tons.

"Looking ahead, human nature being what it is, we can probably continue to count upon a reasonably constant increase in population; this factor alone will justify a limited expansion of the market for most of our end products. To justify continuance of the expansion rate to which we have become accustomed, however, we must maintain the historical rate of increase in the major component of growth, namely, per capita consumption. This will not be easy for this historical rate of growth has been high. It has been high for two reasons: (1) because the industry has been able to develop an ever-widening range of end products designed to meet consumer needs, and (2) because the over-all economic and political climate has been such that the consumer can afford to buy these products in ever-increasing volume.

The Over-All Economic Climate

"As to the basic soundness of our American economy and the ability of the American consumer to continue buying our products in ever-increasing volume, I am still the 'perennial optimist' that some have labeled me. We have not abolished the business cycle, but we have learned most in this country about the control of cyclical fluctuations. Basic readjustments in our over-all economy have been completed during 1954 with little or no loss in disposable personal income or consumption expenditures, and little or no change in savings or the investment potential represented by savings. Historical precedent to the contrary, I believe that, with *competent economic and political leadership*, we can keep our over-all national economy strong and healthy and continue to avoid serious depression and large-scale unemployment in the future.

"With adequate natural resources and adequate productive facilities, there is not sound reason why our problems of distribution cannot be solved, and the 'boom or bust' pattern put to rest. I look for continued long-term improvement in this country's productivity and in its basic living standards.

"At the same time, however, we should bear in mind that some of the economic and political factors that have contributed to our per capita growth in recent years may not be operative in the future or, if operative, may be less potent in their impact upon future paper requirements. The accumulated unsatisfied demands of the war period, for example, have long since been fully met, and there is no longer a lag in our long-term rate of growth attributable to a deferment of normal expansion as during the war.

"Further, our recent expansion has already taken into account the needs of national defense in the event of a new national emergency; the preparedness program recommended by the defense authorities is about completed, and the need for new facilities for defense will be a relatively minor consideration in considering the justification for further expansion. Similarly, in our forward planning, we can perhaps assume that foreign aid, economic assistance programs, and federal government expenditures will generate a relatively lower paper and paperboard requirement in the future than they have in the past.

"If the rate of growth in per capita consumption is to be maintained, other new uses must be found. This will require much inventive genius on the part of our product development departments. We all employ that we consider mighty smart people in our development departments and if, in their combined efforts, they have overlooked some new product development requiring the use of a substantial tonnage of paper or paperboard, then perhaps we have overestimated their ability.

MARKET DEVELOPMENT

"While I am generally optimistic as regards the forward trend of our over-all national economy, my optimism in respect to the ability of the paper industry to generate consumer demand for its products as effectively in the future as it has in the past is more restrained. In the absence of more tangible evidence of constructive new market development in this country, excessive optimism in respect to the prospective growth rate for domestic paper consumption does not appear to be justified.

"The high rate of growth in per capita consumption of paper during recent years has, for the most part, been a result of *ideas* born in sweat and blood during the worst economic depression in the nation's history. The existing green pastures of the paper industry at that time were relatively few, and never more unfertile. Market development was a matter of the starkest economic necessity. New pastures had to be invaded and the old ones cultivated to support life in the industry.

"The largest pastures selected for invasion were in the fields packaging and building. Paper succeeded in gaining a foothold in these fields because it was found that it could supply serviceable products for these markets at less cost than competing industries. The same poverty that created the famine, with a little nudging, created the demand for new paper products that were less expensive than other products serving the same markets. Continually increasing labor costs which created the need for automatic or mechanical packaging have also contributed to our increased use of paper products. The same labor cost situation has forced a new method of food distribution in which eye-appeal and shelf-life of the product in packaging play a very important part.

"The growth in per capita consumption in the past 20 years has been attributable in large measure to the successful exploitation of these basic marketing ideas. Improvements in quality, over the years, have enabled us to establish a beachhead and consolidate our gains in these major markets. Today, over half of our total paper and board consumption is used for packaging purposes. The building industries have become the outlet for an increasing share of our total paper supply.

"Whether we can continue to maintain the spectacular growth rates of the past in these important segments of the economy is open to some question. The *obvious* potential markets for packaging and building materials have been pretty thoroughly exploited. In these particular fields, our market research in the future must be directed to the less obvious.

Further, as the quality of our products has improved and as competition for basic wood supply has increased, our costs have gone up.

"While we still enjoy a competitive advantage in these markets, both from the standpoint of relative cost and relative serviceability, the profit margin of our competitive advantage is perhaps shrinking. Increased competition from without the industry is inevitable and the future of our growth rate in these segments of the industry will depend in part upon how successfully we meet this new challenge.

"Sanitary products for household and industrial consumption have also contributed significantly to the recent increase in per capita paper consumption in this country. Consumption of sanitary grades, due in part to *new* product development, has tripled since 1937. World War II, with its attendant labor shortages, provided the chief incentive for this spectacular market development. Here, too, the ground gained is rapidly being consolidated. There may well be practical limits to our ability to find new applications of a sound basic idea that has already been well exploited. Fresh ideas and new products will be needed to keep the growth rate as dynamic in the future as it has been in the recent past.

"Too rigid reliance upon historical *patterns* of growth has perhaps in the past been a common fault of those who have built the productive capacity of this industry. The tendency has been to examine growth trends in the industry and to build new capacity for the manufacture of those products for which the historical growth rate appears to have been highest. Everyone wants to join the high man on the growth rate totem pole—few pay much attention to the low man. Carried to extremes, such a policy can be disastrous. Profitwise, it could knock over the whole totem pole.

"There are opportunities for intelligent market development in *every* segment of this industry—not just in those segments that have come to be regarded as Cinderellas. Our market research programs must encompass the whole front, not just segments of it, and our future plant must be built with due regard for the whole pattern of growth of consumptive requirements. Otherwise, we may wind up with plant facilities that are lopsided in relationship to the new pattern of requirements. Within limits our errors of judgment can be corrected later by grade shifting, but we can save ourselves this needless expense if we plan wisely in the first instance. The approach to market research must be both selective and rational. It must be based upon realistic appraisal of consumer habits and consumer needs, not as of yesterday, but as of tommorrow.

"In our forward planning, of course, the possibilities of further market development abroad will not be overlooked. We know that, outside of North America, average per capita consumption of pulp and paper, despite spectacular improvement in recent months, is still less than it was prewar. For this reason, the potentialities of growth are relatively greater abroad than they are at home. We know, too, that improvements in the pulp and paper economies of the Old World, for the foreseeable future, must be based upon either North American fiber or North American end products. Beyond this, however, we know little about the basic factors that will affect forward trends in the pulp and paper economies of the Old World.

"More extensive market research abroad, a better understanding of trends in those industries that consume pulp or paper, and a more intensive study of trade and currency problems are prerequisites for intelligent export development. Foreign markets undoubtedly will absorb more of our products in the future than they have in the past. The important question, however, is how much more? Expansion of domestic facilities to supply export markets will necessarily be a more speculative venture than expansion to supply domestic needs. To the extent that we can learn more about the potentialities of these export markets, the element of risk in this type of expansion may be significantly reduced.

PATTERNS OF FIBER CONSUMPTION

"The second factor that has accounted for the very high rate of fiber consumption in the domestic paper and board industry has been the rapid rise in the relative importance of wood pulp in the over-all fiber furnish of paper and paperboard.

"In 1946, at the beginning of the postwar expansion cycle, 58% of our total fiber consumption in paper and paperboard was wood pulp; last year 65.6% of the total furnish was wood pulp. This is not surprising in view of the marked trend toward integration in paper and paperboard production.

"What is significant, however, is the fact that if furnish ratios had stayed where they were in 1946, we would be consuming 2,172,000 tons *less* wood pulp than we are currently using. In other words, one-third of the postwar growth in pulp consumption by the paper and board industry has been attributable to furnish changes; only two-thirds of the total increase has resulted from growth in paper and paperboard production and new uses.

"The installation of new integrated pulp and paper capacity, in addition to increasing the supply of paper made from virgin wood pulp, also operates to increase the potential supply of salvageable waste paper. In 1946, we recovered in the form of waste paper 32.3% of the total domestic supply of paper and paperboard; by the first half of this year, our salvage rate had dropped to 26.2%. Expressed differently, waste paper consumption in 1946 was equal to 60% of wood pulp consumption.

"The addition of 10 million tons of wood pulp capacity during the postwar period, on this basis, indicates a potential addition to the waste paper supply of 6 million tons. The actual increase in waste paper consumption between 1946 and 1953 was only 1.25 million tons. The unused increment in the waste paper potential would accordingly appear to be of a magnitude of 4.75 million tons, or four-fifths of the total potential generated by the recent expansion of the wood pulp industry. It must be recognized, however, that a large part of the paperboard tonnage which we would normally recover went abroad, and it was not economically sound to attempt recovery.

"The point of all this is that the availability of this increased potential supply of waste is a factor that must be taken into consideration in considering future expansion of our pulp and paper facilities. As the supply of recoverable waste increases in relation to the demand, an ancillary expansion cycle could at some point begin in those segments of the industry that depend upon waste paper and market pulp.

"Relative economics will, of course, determine the pattern of fiber consumption upon which the paper and paperboard industry's long-range growth will be based. My own views are that, to the extent that waste from paper and paperboard made from improved quality of pulp is economically recoverable, it will gradually find a use and that the relatively more favorable increase in the use of wood pulp versus waste will not continue for long at the postwar rate. If, in fact, we are to use relatively more waste in the over-all furnish of paper and paperboard in the future, we must make certain that, in our forward planning, we do not construct duplicate sets of facilities, one based primarily on virgin fiber and the other primarily upon waste to serve the same end markets. To the extent that we do, we are inviting trouble.

"I would like to make one observation as to potential waste paper supply in the short-range period and that is, I think too few of us realize how much waste paper is being made nonusable through coatings and additives of various kinds in the original furnish of the paper and paperboard. Until our research departments find out how to make this usable, users of waste papers and the waste paper dealers may have some severe headaches."

R. G. Macdonald, speaker at Western District's meeting of Dec. 1, 1954

You members of the Technical Association are the ones who are largely responsible for the use of additives and coatings to improve the serviceability of products. If we are to maintain the proportionate use of waste papers you are the group who will have to find a way to take the additives out and the coatings off in order to make the waste generated in the manufacture of these products and the used products themselves usable as a reuse fiber component.

You fellows have been the cause of more disturbing headaches for management over the years than any other group, including customers. Now you have a chance to demonstrate your aspirin ability by helping to cure the headaches you have created. Progress is attained only by blood, sweat, and tears, and I agree with Bernard Baruch that there is only one cure for our individual and collective ills and that is—WORK!

The recent ruling to permit aluminum foil inserts in magazine advertising sections will also cause numerous headaches for the members of the Superintendents' Association, as will the additives and coatings previously mentioned. This waste paper situation will get worse before it gets better. The means of making these special papers and paperboards usable fiber will be one of our most engrossing projects in the immediate future. In an area which has historically consumed such great quantities of waste paper, this matter should be deeply interesting to all in this territory.

In 1945 I had a hunch that the relative proportion of waste paper use would decline and I think the history of the past 10 years has confirmed this. Unless we do something about this matter it will further decline which, in my opinion, is a great economical loss.

As to the future and what might be termed a "preview" of the industry, I would like to call to your attention the summary of the reports prepared by the Stanford Research Institute for the Weyerhaeuser Timber Co., entitled "America's Demand for Wood—1929–1975." This is a very exhaustive study of wood consumption and deals with paper and paperboard consumption as one section of the report (see January, 1955, *Tappi*).

The conclusion reached in this report is that in 1975 the consumption of paper and paperboard will have reached 53.5 million tons, an increase of 21.5 million tons over present consumption. Based on my old rule of thumb formula of a million tons to each 10 billion of gross national product, this would figure out 910,000 tons per 10 billions of G. N. P.—about 9% variation from the old formula. Much of this can be accounted for in the improved quality and consequent decrease in weight of paper and board since the formula was used by me as a measuring stick of consumption.

I have used several times the story of the old Arabian proverb which read, "All mankind is divided into three classes—those that are immovable, those that are movable, and those that move." In this instance, I think the early advantage of the use of these specially treated papers and boards will go to the one who moves!

I believe the paper industry will continue to grow and consumption of its products increase, but not quite at the percentage rate it has increased over the past 15 years.

It has been a pleasure for me to talk to you and I think you need have no misgivings about your having allied yourselves with one of the most important industries in the economy of the United States.

Part of group in attendance to hear R. G. Macdonald's talk on "The Services of TAPPI to Pulp and Paper Company Management" at the Western District, Empire State Section meeting

Sulphite Pulping as Related to Stream Problems in the Midwest

N. L. MALCOVE

ORGANIZED attack on the problems of stream disposal of spent sulphite liquor in the Lake States area has been the sole objective of the Sulphite Pulp Manufacturers' Research League since its organization 15 years ago by 14 pulp mills in Wisconsin and Michigan. Every effort has been made to develop practical methods of immediate worth in helping member mills reach compliance with the requirements and regulations of State control authorities. Lately the controls have shown a tendency to become more rigid. This results in steady and increasing pressure on the mills to find disposal methods and processes which can be adopted and still maintain the over-all competitive situation; especially is this true for the smaller pulp mills.

Midwestern industry is becoming increasingly aware that waste disposal is to be considered a legitimate and permanent charge on the cost of remaining in business, but as yet the sulphite pulping industry cannot claim to have found any one waste treatment process which is universally adaptable. Well-considered application of available processes, coupled with careful use of the natural treatment capacity of receiving streams, and long-range research and development of markets for lignin and sugar by-products presently offer the best solutions to the problem in our area.

Sulphite pulp mills in the Research League membership vary widely in size, type of product, type of liquor collection systems available, and in availability of capital. This has necessarily led to League evaluations of hundreds of ideas and processes; only a few of which were found to be commercially feasible. Those with sufficient promise have received intensive study, laboratory development, and finally pilot and economic evaluation by the League staff in close cooperation with the technical staff members of individual mills.

Research projects being actively studied by the League at the present time are: evaporation of spent sulphite liquor, burning of spent sulphite liquor, road binder, soil studies, ponding, briquetting, Torula yeast, other biological processes, basic carbohydrate research, basic lignin research, and insolubilization of lignin.

The Research League maintains its own offices and laboratories located at The Institute of Paper Chemistry, and its pilot-scale operations at the Interlake mill nearby.

N. L. MALCOVE, Technical Superintendent, Northern Paper Mills, Green Bay, Wis.

Several of the processes studied by the League have advanced through the pilot stage into large-scale commercial installations at member mills.

There are now in Wisconsin three commercial evaporation plants for spent sulphite liquor. All of these plants have installed Rosenblad-type evaporators with channel switching. Two of these plants have capacity to evaporate and burn substantially all of their spent sulphite liquor. The evaporation and burning plants have not been long enough in operation to have reached maximum efficiencies nor to have reliable costs on the over-all operations.

The production of Torula yeast from the sugars of the spent liquor has been under way for 5 years at one member mill and a new and larger yeast plant is under construction at another mill at the present time. The production of yeast appears technically feasible but a major question remains as to how much expansion can be developed in a market which is now very limited and in high competition with other products in the nutritional field.

A large amount of spent sulphite liquor has been absorbed as road binder in the State of Wisconsin. During 1953, 50 million gal. of liquor were used for this purpose from Wisconsin mills. For some mills especially well situated, it has been found possible to utilize large quantities of liquor for road binder. It also appears that more and more liquor will be used for that purpose. Costs for the road binder to the consumer have been confined largely to transportation charges. The manner of application to roads is by tank trucks equipped with spraying equipment. The tanks are usually of 3000 or 4000 gal. capacity and are made of type 304 stainless steel. Since the road binder usage is a seasonal operation, several alternates have also been under study, such as ponding or lagooning.

An interesting outgrowth of the ponding studies has been a new evaluation of using the soil as a method of microbiological processing similar to a trickling filter. In porous sandy soils the liquor has been found to seep slowly through and strong evidence of bacterial action has been observed. The removal of sugars and of their B.O.D. from the liquor by soil filtration is now a subject for major study by the League and its members. It seems possible that a definite plus value can be achieved by application of controlled conditions for soil filtration.

Agricultural uses for spent sulphite liquor have been the subject for field trials but with indecisive results in most cases. Here again further study may lead to an appreciable usage.

Soil conditioning and soil stabilization studies have been undertaken in League test plots and in university experimental stations. For certain types of soils these studies have shown some promise of utilizing spent sulphite liquor advantageously in one manner or another.

Lignin utilization is becoming increasingly important but as yet the market has remained quite limited when considering the industry as a whole. Long-term research in this field has been conducted for the League by contract with the Organic Chemistry Staff of The Institute of Paper Chemistry.

A complete review of the spent sulphite liquor research and development work in the Midwest area would be very time-consuming. Outside of the League activities, Marathon at Rothschild has for many years pioneered the development and sale of lignin products.

Suffice it to say that every sulphite mill in the State of Wisconsin is doing something to alleviate the streams by some means or another, whether it be evaporation and burning, yeast, road binder, product development, ponding or lagooning.

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Some Stream Pollution Problems and Abatement Measures Undertaken in the Pacific Northwest

H. R. AMBERG

A problem of importance associated with the acid pulping process is stream pollution. In the Pacific Northwest we have been rather fortunate in that most of our mills are located on sites having ample dilution water. There are a number of rather simple methods used in the Northwest which have been effective in reducing localized pollution associated with the process and it is of interest to note that in many instances these methods have been as effective as recovery.

The problems associated with the discharge of spent sulphite liquor may be classified as follows: (1) visual, (2) oxygen depletion, and (3) excess slime growth. The visual objections encountered in spent sulphite liquor discharge are foam and color. In many instances a simple log boom has been effective in holding back the foam, and in some instances foam breakers have been installed that have successfully eliminated this objectionable problem. Excessive discoloration can, in most instances, be handled by installing an underwater outfall which also has the advantage of hiding the effluent. It is, of course, a good public relations measure to have all of the outfalls discharging below the water surface to such a depth that they cannot be seen.

Oxygen depletion of water receiving sulphite pulping wastes has undoubtedly been one of the major problems of the industry. This problem, of course, can be handled effectively by recovery. However, in the Pacific Northwest the oxygen problem will only be encountered for approximately 120 days of drought flow, and in many instances simple methods of impounding and diffusion have attained results satisfactory to the regulatory agencies. For example, in situations where dilution water has been adequate the installation of underwater diffusion lines has accomplished reductions of localized pollution in excess of 90%. At Everett Harbor, the spent sulphite liquor from the production of 900 tons of pulp is discharged through a 30-in. line into 300 ft. of water. The outer 1000 ft. of the 3000-ft. line contain diffusion nipples which diffuse and distribute and waste into the lower strata of the harbor. Locations which previously did not meet the State standard of 5 p.p.m. D.O. now contain an adequate supply of oxygen. Here, then, is a method of more effective utilization of the available dilution water which possibly has been as effective as recovery.

In the Columbia River, which has a drought flow of about 80,000 sec.-ft., the discharge of spent sulphite liquor near the shore line resulted in excessive bacterial slime growths. These growths of *Sphaerotilus*, which are dependent upon the sugar fraction, would multiply to such levels that they would clog the gill nets of the commercial fishermen in the area. During certain periods of the year fishing was impossible because of the excessive growth. Previous studies indicated that as long as the spent sulphite concentration was less than 5 p.p.m. of moisture-free solids no significant growth would develop. Because sufficient dilution water was available in the Columbia, it was decided that underwater diffusion lines would be effective in diluting the liquor below the minimum concentration necessary for growth. Since the underwater lines have been installed, the waste concentration in critical areas along the shore line has been reduced by 95% and the growth has been estimated to be reduced by more than 90%. Here again a simple method of more effective utilization of the receiving water has been effective in attaining high pollution reductions.

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The Willamette River has always presented a problem of oxygen depletion during the critical low flow period in the Summer. Four sulphite mills on the main stem discharge water from the production of 500 tons of pulp per day, or a waste equivalent in organic pollution to a population of roughly 2 million. Three of the mills have been using impounding installations to store the waste liquor during the critical low flow period, and discharging the waste in accordance with flow during the high water period. The fourth mill has initiated a road binder and barging program, the concentrated liquor which is not used for the treatment of roads being barged to the Columbia River where it is discharged into an ample supply of dilution water, Of course this latter program, as well as a lagoon program of limited capacity, require efficient recovery of concentrated liquor from the blow pits. As a rule, with conventional washing systems, about 50% of the solids can be recovered at about 10% solids, and with padding this figure may be increased to 60 to 70%. It appears that several of the mills will have to improve their collection operation to meet the stringent standards.

Another problem encountered with the storage ponds is seepage. At the present time only one lagoon has presented a seepage problem, and in this case seepage has been reduced by treating a portion of the bottom with portland cement and treating the sides with a low viscosity tar. Most of the seepage has been collected in a common collection system and it is planned to pump the seepage back to the pond.

Another problem encountered in our Willamette River abatement program may have application to other localities. We have noted that in certain stretches of the river the improvement as observed in the D.O. profile has not been proportional to the degree of pollution reduction. It is well known that when a nutritionally deficient waste such as spent sulphite liquor is mixed with a sufficient quantity of domestic sewage the nitrogen or nutritional requirements for the stabilization of the waste will be supplied by the excess nutrients contained in the sewage, and a limited supply of nitrogen will limit organic decomposition accordingly, the rate being limited by the rate at which microbial death permits the limited supply of nitrogen to be reused by successive generations.

From laboratory experiments it has been determined that various loadings of spent sulphite liquor added to Willamette River water will decompose at various rates, or a decrease in the amount of organic pollution discharged has resulted in a consequent increase in the rate of oxygen utilization. For example, by reducing the pulp mill load by 50%, we have noted a twofold increase in the rate of biochemical oxygen utilization, thereby masking a considerable portion of the expected improvement in the D.O. profile. Now it can be seen that by increasing the amount of available nitrogen per unit of organic material the rate of oxygen utilization can be increased. This substantially would be the picture if any of the Willamette pulp mills converted to the ammonia base without plans for recovery. The increase in available ammonia would be reflected in the D.O. profile of the stream by an increase in the D.O. deficit and a shifting of the deficit toward the source of pollution. This might also result in more rapid recovery of the stream.

Before any change in the pulping base is contemplated, a very thorough examination should be made to determine how the addition of ammonia will affect the receiving water. In some instances, where nitrogen is not a limiting factor, the conversion may not alter stream conditions, but in other instances when a definite nitrogen deficiency exists, the addition of nutrient will certainly alter stream conditions under similar pollution loadings.

Another problem which comes up with reference to ammonia-base liquor was the belief that the additional ammonia in the waste would stimulate excessive slime growth (*Sphaerotilus*). Some cursory laboratory studies, however, indicate that the organism does somewhat better on calcium than on ammonia-base liquor at waste liquor concentrations normally found. It appears that the additional ammonia stimulates the competitive bacterial population which reduces the substrate below the minimum concentration required for excessive *Sphaerotilus* growth.

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Sulphite Pulping as Related to Stream Problems in the Eastern United States

VANCE P. EDWARDES

Irrespective of the location in continental United States, the problems of stream pollution by sulphite waste liquor are common to all. Differences are largely a matter of size, both of the mill and the body of water which receives the mill discharge.

The first installations for waste liquor utilization were based on economic factors rather than a desire to reduce stream pollution. About 1906, or possibly before, a yeast plant was built at a New York State mill but the process was abandoned because of inability to control the purity of the yeast. Following this venture, the same mill installed evaporators and driers producing concentrated liquor and dried powder. Shortly after, several similar plants were built in the East and in all but one case, the motivating reason was economy. During World War I an alcohol plant was built and operated in New York for a few years. However, operation was discontinued when it was no longer economical.

The production of valuable by-products from waste liquor has intrigued the industry since the sulphite process was first developed but, so far, no product has been developed which offers an economical outlet for the entire industry. For the present crude by-products, the market is definitely limited. In the words of the late Bjarne Johnsen, anything can be made out of sulphite waste liquor but money.

Later, when stream pollution became an important factor, means of disposal, other than economical, were considered. Because of the tonnages involved, it became apparent that the disposal had to take place either in the mill or closely adjacent. This conclusion brought up the question of means. Irrespective of the per cent of liquor collected, the production of either yeast or alcohol reduces the B.O.D. of the liquor by only about 50%, so if 50% of the total solids is collected, the above processes result in only a 25% reduction of pollution. Obviously other means had to be found which would satisfy the state and federal authorities.

With economical means of waste liquor disposal practically ruled out, attention turned to other methods. These were: (1) lagooning, (2) use as a road binder, (3) artificial aeration, (4) soil conditioner, (5) controlled production, and (6) burning.

Lagooning has been practiced with minor success and some outstanding failures for some years. The dangers arising from lagooning are two: first, contamination of the wells in the vicinity, and second, seepage of the liquor into the stream before the oxygen demand had been satisfied. However, with proper selection of the site of the lagoon and its construction, some stream conditions in the East have been improved. Where a mill is located on tidewater, lagoons have been used to store the liquor, releasing it as the tide is going out.

While the Midwest has had notable success in promoting the use of digester blow liquor for road surfacing, not much has been accomplished along those lines in the East. Some years ago, relatively small amounts of concentrated liquor were used but the cost and freight charges made it uneconomical. For a mill located close to the point of application

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and with the proper type of soil, it would be possible to dispose of a reasonable amount of liquor during good weather, which coincides with low stream flow, at little or no cost. However, most soils in the East are lacking in clay, an essential ingredient for the successful application of sulphite waste liquor.

Artificial aeration of the stream has been tried; also, aeration of the liquor by spraying but with indifferent results.

While there is some value to waste liquor as a soil conditioner and encouraging results have been secured experimentally, the question is again one of economics.

There exists a situation in the Northeast, where the production of three mills, during low water, is under state control—not a nice situation. These mills are now lagooning and achieving some degree of success but the stream is in such poor condition, due to fiber deposits accumulated over the years, that no immediate relief can be foreseen.

Burning of the waste liquor, with the attendant problems of collection and evaporation and with no chemical recovery, holds very little hope as a solution for mills using a calcium base and with production of 150 tons a day or less. The investment cost is high and the return from the fuel value of the concentrated waste insufficient to pay carrying charges on the investment, unless the mill is located in a very high cost fuel area. However, should a mill need extra boiler capacity and the furnace required for burning waste liquor is charged off against steam generation rather than liquor disposal, the project becomes more sound economically.

Burning a calcium-base liquor introduces the problem of air pollution from fly ash and sulphur dioxide, either of which can bring about serious conditions. Fly ash disposal in itself is a major problem; it weighs only 2 lb. per cu. ft. piled loose and to discharge it into the stream is no solution. The sulphur dioxide concentration in boiler stack gas, when burning 100% waste liquor, varies from 0.5 to 1% depending upon combustion efficiency. Lengthy experiments have shown that sulphur dioxide concentrations as low as 2 p.p.m. can, under proper conditions, cause crop damage.

Although all the foregoing applies to calcium-base liquors, much is common to the various soluble bases. While several eastern mills are using soluble-base acid, none, as far as known, are recovering chemicals. Except in special cases, i.e., the wider use of woods or the production of special pulps, recovery of both the base and sulphur dioxide is required to make the process economic. This means a high investment cost in collection, evaporation, burning, and recovery installations and again, the feasibility is governed by the size of the mill.

The decision as to the type of disposal to use depends then on mill size, stream flow, rulings of the regulatory officials, types of wood available, and pulp quality desired. To date, on this continent, there is only one soluble-base mill recovering chemicals, magnesium oxide, and sulphur dioxide, although another has reported recovery of sulphur dioxide from an ammonia-base liquor.

It must not be thought that scaling troubles in heaters and evaporators will completely disappear through the use of soluble bases. Enough calcium is in the wood to form scale and while the severity is greatly reduced, it is still a problem.

There is no doubt that, because of increasing pressure from public officials, heightened by the activities of small groups, sulphite mills will have no choice in the matter. They will have to, by the most suitable means, reduce the discharge of waste liquor into the streams, whether it is an economical operation or not.

Insofar as sulphite mills in the eastern part of the United States are concerned, not over six out of a total of 28 are of such size that an economical solution of the problem is possible.

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Pyrenone-Treated Papers for Grains and Cereals

HAROLD R. ALLEY

The shipping and storage of huge tonnages of grains, cereals, and allied products present a tremendous problem in the prevention of insect infestation. One major source of infestation is during the bulk shipment of grains or cereals in railway box cars. Insects become established in accumulations of waste materials behind the car linings, in floor cracks, or related crevices. Demonstrations have shown that it is impossible to remove all the insects either by mechanical means or by extensive fumigation of the box car. When infested cars are loaded with fresh grain, flour, or cereals the insects are attracted to the food product and additional infestation occurs. A second major source of infestation is through the penetration of packaged food containers by the same grain and cereal insects. Penetrated containers result in direct damage of the food product as well as destruction of the moisture and dirtproofness of the container.

It is rather difficult to establish exact figures for the nation's financial losses due to insect infestation because of the immensity of the entire agricultural setup. This setup includes grain elevators, transportation and milling agencies, distribution channels, as well as Mrs. Jones' pantry.

H. E. Gray, cereal packaging technologist, indicates that one study of "hot roll mix" packages showed insect infestation of 19% of the packages in 2 months' time (August and September).

Roughly speaking and on a very conservative estimate, 10% over-all product losses in the field of grains, flours, and cereals would amount to an enormous financial loss to the nation.

The U.S. Department of Agriculture and the Federal Security Agency is attempting to prevent the use of insect and rodent contaminated grain for human food consumption. A regulation which went into effect July 1, 1953, empowered the FSA to seize wheat or grain which the government deems unfit for human consumption. This spoiled or infested grain would automatically be diverted to livestock feed purposes, i.e., hog feed with attendant financial loss. Under these regulations, grain containing 20 or more insects (dead or alive) or containing 80 weevil-damaged kernels per 1000 grams will be condemned.

KINDS OF INSECTS

For the layman, it can be stated that the insect group is the largest group of animals in the world. Over 600,000 species have been identified. Insects are divided roughly into 25 orders, such as moths, termites, beetles, etc. In New York City alone, over 15,000 species have been found. There are over 1000 species in almost any specific locality. It has been estimated that 10% of our crops or billions of dollars are lost annually due to insects.

If specific problems of identification or control of specific insects arise, contact your local University, Board of Health, or County Agent as well as the Bureau of Entomology, U.S. Department of Agriculture, Washington 25, D.C. Also consult the nearest public library.

The research department of the supplier of Pyrenone lists the following insects which are affected by Pyrenone:

Rice weevil	Dark meal worm
Drugstore weevil	Clover mite
Granary weevil	Silver fish
Saw-toothed grain beetle	Cockroaches
Rust red beetle	Cheese skipper
Cigarette beetle	Buffalo gnat
Confused flour beetle	House flies

Harold R. Alley, Technical Director, Mid-West Wax Paper Co., Fort Madison, Iowa.

Spider beetle	Horse flies
Colorado potato beetle	Horn flies
Blister beetles	Deer flies
Cadelle	Lice
Mediterranean flour moth	Ticks
Chocolate moth	Spiders
Grain mite	Little black ants
Angoumois grain moth	Fruit flies
Scorpions	Bald faced hornet
	Polistes wasp

METHOD OF INSECT INFESTATION CONTROL

Food experts agree that there is a definite need for control of insect infestation of grains and cereals. Many insecticides and methods have been tested with varying degrees of effectiveness. New control methods are being studied by many industrial and governmental agencies.

One of the most recent advances in infestation control is the treatment of paper and paper products with a combination of piperonyl butoxide and pyrethrin. These two chemicals or insecticides when properly combined are known as Pyrenone. This combination is one of the most effective found to date for the prevention of insect infestation.

Pyrenone is an oil-base insecticide consisting principally of piperonyl butoxide with 10% added pyrethrin for maximum insecticidal effectiveness.

Piperonyl butoxide is a recently developed, synthetic, organic insecticide. It is the chief component of Pyrenone. Its chemical name is 3,4-methylene-dioxy-6-propylbenzyl (butyl) diethylene glycol ether. Piperonyl butoxide is only moderately toxic to insects.

Pyrethrin is an old "stand-by" in the insecticidal field. It is very widely used in many different formulations of pest control agents. Pyrethrin has rapid and potent knock-down power on a wide variety of insects but is inadequate alone for permanent killing effect. When piperonyl butoxide is combined with pyrethrin, a surprising and synergistic effect (insecticidal) is obtained.

Pyrenone—Properties and Tests

Any useful insecticide for the prevention of infestation of grains and cereals must be safe for food products, stable for extended periods, and effective in both paralytic and repellent action on the insects which commonly infest grain. Pyrenone has been shown to possess all these properties. The safety of this insecticide has been demonstrated by acute and chronic toxicity tests over a period of more than 4 years.

The U.S. Department of Agriculture has stated that there does not appear to be any health hazard connected with the use of this insecticide providing it does not come in direct contact with the finished food product.

In experimental tests, treated kraft paper showed no reduction of piperonyl butoxide or pyrethrin content by chemical analysis after heating at 150°F. for 24 hr. Treated wax paper remains fully effective for periods exceeding 1 year as evidenced by penetration time and other tests.

Tests have been conducted on multi-wall, paper, flour bags, by a large bag manufacturer. After 2 months, the Pyrenone-treated, multi-wall bags were completely resistant to all insects used.

A special test by the supplier of Pyrenone involved the placing of 50 flour beetles on a Pyrenone-treated kraft paper under a Petri (glass) dish. The percentage of knock-down was observed at various time intervals. The results of these tests are as follows:

Kind of paper	*Per cent of knock-down* 2 hr.	4 hr.	24 hr.
Untreated kraft paper	0	0	0 (no effect)
Pyrenone-treated kraft paper	5	42	96 (very effective)

A long term test was conducted for the time required for penetration of treated papers by cadelle larvae, a boring insect. Pyrenone-treated and untreated kraft papers were placed over a tray containing wheat heavily infested with cadelle larvae. Observations were made daily to determine the first insect penetration. The results are given below:

Kind of paper	*Average time for first penetration, days*	*Dosage, piperonyl butoxide,[a] mg. per sq. ft.*
Untreated kraft	8	0
Pyrenone-treated kraft (oil type)	271	50
Untreated waxed kraft	22	0
Pyrenone-treated waxed kraft (Mid-West type)	392	58

[a] Chief component of Pyrenone.

It is interesting to note in the above table that the Pyrenone-treated waxed paper shows a noticeably longer penetration time than the oil treated standard unwaxed kraft. The oil-type treated paper is not as effective as the wax coated Pyrenone-treated sheet which protects against infestation for over 1 year.

Additional tests have shown that Pyrenone is effective against a wide variety of insects including cadelles, all common weevils, grain beetles, grain borers, moths, yellow meal worms, grain mites, cheese skippers and mites, houseflies, cockroaches, mosquitoes, ants and many others.

Pyrenone-Treated Waxed Papers

Over a year ago, Mid-West Wax Paper Co. began investigating the use of Pyrenone treatment of waxed papers. Extensive research was carried out to find the most practical and effective method of this treatment for prevention of insect infestation. Samples were prepared and sent to various grain and cereal shippers, packagers, paper merchants, and governmental agencies for evaluation. As a result of this research program, it is believed that these insect-repellent papers are the most effective on the market today.

The Pyrenone-treated waxed papers are currently being produced by Mid-West in two types. It is produced from 40-lb. bleached or natural kraft waxed-one-side to 48 lb. The wax contains the recommended 55 mg. of Pyrenone (active ingredient) per sq ft of paper, or 0.5 lb. per ream. It can be produced in various widths, up to 60 in., in rolls of various diameter, or in sheets of almost any size. The Pyrenone-wax treatment can be applied to various weights of bleached or unbleached paper stocks, and if desired, printed papers (wax coated one side) may be used for package overwraps. It has become a standard production item, and can be produced in any desired quantity up to carload lots.

A recent letter from the U.S. Department of Agriculture expressed great interest in Mid-West's method of treatment. They desire the results of additional field evaluation of these papers for protection of all grain and cereal items to supplement their laboratory results. Railroad claim officials have expressed considerable interest in the product as a means of reducing their losses due to damage from insect infestation.

Type of insect	*Initial activity*	*Final result*
Wasp	Avoided treated paper	Down in 30 min.; dead
Cricket	Avoided treated paper	Not stunned or killed; alive
Large black ants	Avoided treated paper	Down in 30 min.; dead
House flies	Avoided treated paper	Down in 10 min.; dead
"Anonymous" bugs	Avoided treated paper	Quickly killed
Cockroaches	Avoided treated paper	Down and dead in 24 hr.
Huge Mississippi water bugs	Avoided treated paper	Down and dead in 24 hr.
Large house spider	Avoided treated paper	Spun web to keep off paper

In order to obtain results of our own, Mid-West's testing and research staff conducted tests to determine the effectiveness of the waxed Pyrenone-treated paper on various insects. Six square inches of Pyrenone-treated waxed paper was placed in a 1-pt. glass jar with a ventilated lid. Various insects were added, one at a time, and the insect activity was noted. Some of the results are shown in the above table: Additional insect tests on grain weevil, mosquitoes, etc., are planned as soon as new insects are acquired.

A very effective sales demonstration can be made by acquiring local insects and placing same in a small glass jar. An additional glass jar is used as a test chamber which contains the Pyrenone-treated paper and the insect under test.

In addition to the natural resistance to penetration and repellency action of Pyrenone-treated paper, the treated paper may affect insects in various ways. An insect may be "stunned" or kill by: (1) contact with the paper, (2) eating the paper, (3) inhalation of the insecticide vapor, or (4) a combination of these.

Effectiveness of Various Sheets

Past research on insect papers indicates that there is a sizable difference in the effectiveness of various general types of sheets. Tests on different insecticides and actual production runs indicate the following:

Type of sheet	*General insect properties (knock-down, penetration resistance, repellency, etc.)*
Lacquer coated paper[a]	Least effective
Casein-clay coated paper[a]	Fair
Pyrenone-oil treated paper	Good
Pyrenone-wax coated paper	Very good; highly effective

[a] Insecticide is contained in the lacquer or casein.

Pyrenone Concentration

Production runs and laboratory tests for insect repellency and killing power of the finished papers has been made on the exact concentrations of Pyrenone which were recommended by the supplier. The minimum concentration of Pyrenone to attain maximum effectiveness is 55 mg. of Pyrenone per sq. ft. or 0.5 lb. per ream (50 mg. of piperonyl butoxide and 5 mg. of pyrethrin). Mid-West's insect repellent papers contain these proportions of the two insecticides, namely 0.5 lb. per ream total.

Physical Tests—Plain Kraft (Untreated) versus Treated Kraft

Pyrenone-treated, waxed kraft is produced and sold for its insect resistance rather than its strength properties. The physical strength of the Pyrenone-treated (waxed) paper is basically the same as the untreated kraft base paper, although there is a slight increase in the tensile strength of the treated paper. The waxed-Pyrenone treated paper shows a much lower porosity (air) than the plain kraft. The waxed paper also possesses improved moisture resistance over the plain kraft. Mid-West's Pyrenone-treated papers are produced from high strength, kraft-base stocks and the finished strengths will be comparable to ordinary wax-coated paper of the same or similar basis weights. Physical tests of the plain and treated papers are given below:

Test	*Plain 40-lb. kraft (untreated and unwaxed)*	*Pyrenone-treated 40-lb. kraft (wax coated—one side)*
Bursting strength	33	34
Tearing strength, grams	85	81
Tensile strength, lb./in.	20	25
Porosity, sec./100 cc.	9.3	Very low (several hours/100 cc.)
Moisture resistance	Poor	Good

Additional Comments

The U. S. Department of Agriculture has stated that the Pyrenone-treated paper presents no toxicity problems but should not be placed in direct contact with food products, i.e., coated side out. When the paper is used in this manner, no serious toxicity or contamination effects should result.

Over the past year, Pyrenone concentrates and wax-Pyrenone mixtures have been heated over the hot plate and production runs on the machines have been made in Mid-West's plant. The treated paper has been slit, cut, packaged, and handled. No evidence of ill effects has been noted by any individual.

The mild odor of Pyrenone-treated paper is characteristic of the insecticide (Pyrenone). The presence of the mild odor is somewhat of a gage of the Pyrenone content of the paper and indicates full or adequate potency. It is advised that all users perform and evaluate Pyrenone papers by making actual packaging tests on the specific product to determine the possibility or extent of any odor transfer to the food product. All packaging tests should be conducted by competent technologists. Actually, there should be no permanent odor problem on packaged grains or cereals since the odor is somewhat volatile and if transferred to cereals in minute quantities, the odor should be of a temporary nature.

Pyrenone has been incorporated in oils, ointments, and creams and tried as a fly and mosquito repellent. After smearing the human skin with the ointments, no ill effects have been evidenced.

All food packagers should fully evaluate the Pyrenone-treated paper in their laboratories prior to partial or full scale use. This implies that "rat feeding" tests for toxicity and all other necessary tests will be made by the purchaser or user. Mid-West assumes no liability for improper use of this general type of paper.

Pyrenone-treated waxed paper has proved its effectiveness in preventing insect infestation when used as car liners, multiwall bags, and package overwraps. The effectiveness of the paper against a wide variety of insects suggests other possible applications. Pyrenone-treated papers are being considered as a shelf liner in restaurants, homes, and other food storage locations. The paper should be effective in protecting clothing from moth damage. It can be used as an insect barrier for lining boxes and crates. The U.S. Department of Agriculture suggests the use of Pyrenone-treated paper for the fabrication of multi-wall bags for the packaging of flour, cereals, and grains. Pyrenone-treated paper might well be used for insect resistant floor covering under rugs or linoleums or tile. Dresser drawer liners, textile wraps, overwraps for banana stalks and other fruits or vegetables has also been suggested.

Pyrenone-treated papers have never been fully evaluated against all known insects. It is suggested that this general type paper be tested against all general types of insect problems. The answer as to full insect effectiveness will be found only by trial on the material on specific insects at various locations. Mid-West will be glad to cooperate on new uses or specific insect problems.

SUMMARY AND CONCLUSIONS

Mid-West's Pyrenone-treated and wax-coated insect repellent paper shows great promise in reducing the large financial losses resulting from insect infestation of grains and cereal products. The safety, stability, and effectiveness of Pyrenone have been proved by extensive testing under carefully controlled laboratory conditions. The U.S. Department of Agriculture has been conducting packaged food product tests as well as follow-up field investigations. These papers are currently being evaluated for foreign and military shipments of foodstuffs and grains. This entire project appears quite encouraging at the present time.

Submerged Combustion Evaporation of Neutral Sulphite Spent Cooking Liquor

J. J. OWEN JR., and W. A. MOGGIO

THIS report presents the results obtained during a preliminary investigation of the application of submerged combustion evaporation to the concentration of neutral sulphite spent liquor. This investigation was carried out jointly by the National Council for Stream Improvement and the Ozark-Mahoning Co.; Tulsa, Okla., in the latter's laboratories.

The evaporation was carried out in a 10-in. diameter stainless steel tank, using a $1^1/_2$-in. diameter stainless steel burner. About 30 lb. of spent cooking liquor were charged to the evaporator initially and the level in the tank was maintained by the addition of more liquor as the evaporation progressed. Samples were taken from the tank at intervals as indicated in Table I. After 142 min. of operation, the evaporator was shut down, the product (product 1) drained and weighed, and the burner examined. There was a very small amount of charring around the center section of the burner. After sampling, the product (product 1) was returned to the evaporator and new feed was added to maintain the desired operating level. After an additional 44 min. evaporation, the product (product 2) was drained and weighed. A considerable amount of charring occurred on the burner. Some of the charred material had flaked off the burner and partially clogged the evaporator drain; however, the main portion of the concentrated liquor drained readily from the evaporator.

The data for the two runs and the results of the analyses of the samples taken during the run are tabulated in Tables I and II. A summary of the material balances is presented in Table III; the detailed material balances are appended as Appendix A. A summary of the heat balances and thermal efficiencies is presented in Table IV; the detailed heat balances and thermal efficiencies are appended as Appendix B.

The ratios of solids to sulphur, in Table I, indicate a decided sulphur loss during the evaporation process, which, if a true loss, might limit commercial application of this process. However, there is good reason to believe that the 1.2% sulphur reported for the feed is in error. The member company furnishing the spent liquor for feed has made rough calculations indicating that the maximum sulphur content should not exceed 0.35% on a monthly basis. Any particular sample might be somewhat higher or lower than this, but a value of 1.2% could not reasonably be expected. In view of these questionable results further investigation is necessary to determine whether sulphur is lost during the evaporation.

The material balance for run no. 1 was excellent, showing no apparent solids loss. This is supported by the fact that only a negligible amount of charring occurred during this run.

During run no. 2, there was a considerable solids loss for which there are two explanations. At least part of this loss was due to the heavy charring during this run mentioned previously in this report. The remainder is probably accounted for in the viscous fluid which stuck to the sides and bottom of the evaporator after draining and which could not be weighed. Because of this charring, which could easily cause malfunction of the evaporators, no attempt should be made to increase the product solids content above 60%.

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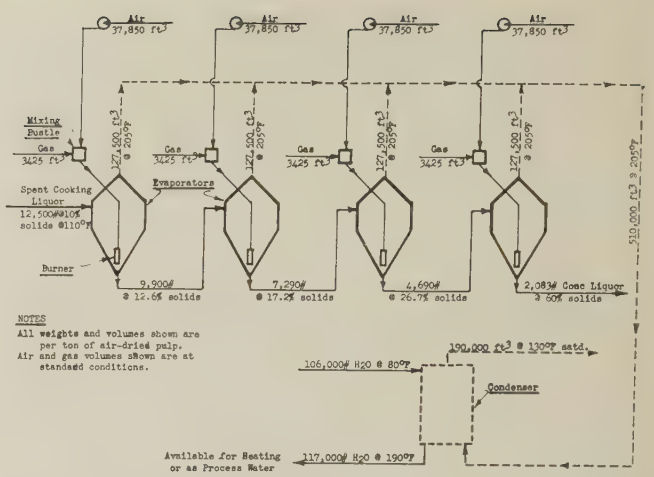

Fig. 1. Flow diagram—submerged combustion evaporation system for neutral sulphite spent cooking liquor

Based on the analyses, there is a slight increase in the acetate content during the evaporation. This is probably caused either by discrepancies in the analyses or because proportionately less acetate than other solids was lost during the charring that occurred.

Thermal efficiencies of about 80% were reached in each run. Although this is a very reasonable efficiency, a higher efficiency may result when larger equipment is used.

An average size semichemical pulp mill at the present time has a production of about 150 tons of pulp per day. Spent cooking liquor at 10% solids would have to be concentrated to 60% solids at the rate of about 1250 lb. of solids per ton of air-dry pulp. That is, for each ton of pulp produced it would be necessary to evaporate 10,417 lb. of water to produce 2083 lb. of concentrated liquor at 60% solids. The following estimates for submerged combustion and quadruple effect evaporation are based on the above average figures. In these cost estimates, only investment, power, and steam costs are considered with condenser water, maintenance, and labor requirements not included.

Based on these figures, Ozark-Mahoning has estimated that a system to accomplish the desired evaporation would cost approximately $150,000, plus erection costs of 10 to 20%. This system would consist of four submerged combustion evaporators, fired independently but fed in series, each with a capacity of 22,500,000 B.t.u. per hr. A complete listing of the necessary equipment for this system and some discussion of other possible arrangements is included as Appendix C.

Table I. Time, Weight, and Analyses[a] of Samples

Sample no.	*Time in evaporator, min.*	*Weight of charge, lb.*	*Weight of sample, lb.*	*Solids, %*	*Sulphur, %*	*Acetate, %*	*Ratio: solids to sulphur*
Feed	..	..	..	6.3	1.2	1.0	5.25
No. 1	30	68.2	1.1	16.9	1.3	..	13.0
No. 2	45	87.6	1.1	24.0	2.3	..	10.4
No. 3	60	109.6	1.2	30.8	2.9	..	10.6
No. 4	75	128.8	1.2	38.1	2.9	..	13.1
No. 5	85	149.6	1.2	36.2	2.5	..	14.5
No. 6	90	159.4	1.2	35.0	2.6	..	13.5
No. 7	105	178.9	1.25	49.3	3.3	..	14.9
No. 8	120	208.2	1.25	44.7	3.0	..	14.9
No. 9	135	228.4	1.3	56.0	3.6	..	15.6
Product 1	142	238.8	..	60.2	3.8	..	15.8
Product 2	44	..	..	75.4	5.1	13.0	14.8

[a] Analyses furnished by R. E. Opferkuch.

Table II. Data

Run No. 1	
Charge (sp. gr. 1.036 at 61°F., pH 6.1), lb.	238.8
Gas rate, c.f.m.	2.02
Length of run, min.	142.0
Final temperature, °F.	205
Product (pH 8.4), lb.	18.2
Run No. 2	
Charge (product from run no. 1), lb.	16.0
Charge (new feed), lb.	68.5
Gas rate, c.f.m.	2.02
Length of run, min.	44.0
Final temperature, °F.	216
Product (pH 8.4), lb.	16.3

A flow diagram, including flow quantities per ton of pulp for the various streams, is shown in Fig. 1.

The above investment cost, plus 15% for installation, is used in the following cost estimate. Power requirements would approximate 600 hp. at $0.01 kw. hr. The cost of gas with a heating value of 1050 B.t.u. per cubic foot is estimated at $0.20 per thousand cu. ft., with a thermal efficiency of 80% for the system. With the initial investment being charged off at 10% per year, and assuming operation 90% of the time, the following costs would result:

$$\text{Investment: } \frac{172{,}500}{10 \times 365 \times 0.9 \times 150} = \$0.35/\text{ton of pulp}$$

$$\text{Power: } 600 \times 0.746 \times 0.01 \times 24/150 = \$0.72/\text{ton of pulp}$$

$$\text{Gas: } \frac{(10{,}417 \times 1000) + (100 \times 1 \times 12{,}500)}{0.8 \times 1050 \times 1000} = \$2.75/\text{ton of pulp}$$

$$\text{Total} = \$3.82/\text{ton of pulp}$$

It may be possible, however, to decrease this cost somewhat, wherever applicable, by recovery of heat from the combustion gases and vapors. This involves the direct condensation of the vapors with water and the use of this water in the process or the transference of a part of its heat content to the feed or other process fluids by means of heat exchangers.

A quadruple effect natural circulation evaporation system with the necessary capacity would cost approximately $350,000 with a steam economy of 3.2 lb. of evaporation per lb. of steam used and steam available at $0.50 per 1000 lb. Power requirements are estimated as about 100 hp. at $0.01 per kw.-hr. With the initial investment being charged off at 10% per year and assuming operation 90% of the time, the following costs would result:

$$\text{Investment: } \frac{350{,}000}{10 \times 365 \times 0.9 \times 150} = \$0.71/\text{ton of pulp}$$

$$\text{Power: } 100 \times 0.746 \times 24/150 \times 0.01 = \$0.12/\text{ton of pulp}$$

$$\text{Steam: } 10{,}417/3.2 \times 0.50/1000 = \$1.53/\text{ton of pulp}$$

$$\text{Total} = \$2.36/\text{ton of pulp}$$

From these rough estimates, it is seen that multiple effect evaporation would cost considerably less than submerged combustion evaporation. The costs used, however, are subject to considerable variation in different parts of the country; these differences may favor submerged combustion in some instances and quadruple effect in others. One big advantage of the submerged combustion system is its much lower initial cost resulting in a lower capital outlay which may be reduced even more in certain cases as described in Appendix C. The estimate above, for the quadruple effect system, does not include any cost for the additional steam load on the boiler which would result from the use of this system. This load would be 3280 lb. of steam per ton of pulp and in most mills this would necessitate additional capital expenditure for expansion of the steam generation plant. The submerged combustion system would have a lower maintenance and replacement cost due to the simplicity of its equipment. In addition, this simplicity would present less opportunity for breakdowns,

Table III. Material Balances in Pounds

Run No. 1			
Solids in	15.05	Water in	223.75
Solids out in samples	4.03	Water out in samples	6.77
Calculated product solids	11.02		216.98
Measured product solids	10.97	Calc. water in product	7.28
Apparent solids loss	0.05	Calc. evaporation	209.70
Solids in product	11.02	Feed	238.80
Solids in samples	4.03		
Water in product	7.28		
Water in samples	6.77	Solids in	15.05
Water evaporated	209.70	Water in	223.75
Totals	238.80		238.80
Run No. 2			
Solids in	13.96	Water in	70.54
Calculated product solids	13.96	Calc. water in product	4.54
Measured product solids	12.30	Calc. evaporation	66.00
Apparent solids loss	1.66		

and down time for maintenance and cleaning would be correspondingly less. Labor with a lower skill level might be used for the operation of a submerged combustion system, and it probably has a greater load flexibility. A further advantage, in many instances, of submerged combustion evaporation is the fact that no additional water supply is required for the evaporation operation as would be required by multiple effect evaporation.

There exists the possibility of the sale of this concentrated liquor to nearby kraft mills for recovery of its sulphur and soda content. The feasibility of this, however, would depend upon an economic evaluation for each individual mill. The sales price of the concentrated liquor (limited by its chemical content and the cost of recovering these chemicals) would have to cover all, or most, of the cost of transporation and evaporation of the spent liquor, making the disposal of this waste economical for the particular mill considering this means of avoiding stream pollution.

The concentrated liquor (60% solids) contains approximately 9.5% acetic acid or about 200 lb. per ton of pulp. For a 150-ton mill this amounts to almost 15 tons of acetic acid per day which might be recovered. At present, acetic acid is being economically recovered from pyroligneous acid liquor, formed by the destructive distillation of hardwoods, contain-

Table IV. Heat Balances

Run No. 1	
Heat in—286.8 cu. ft. gas at 1050 B.t.u./cu. ft.	301,000 B.t.u.
Heat out	
Heating feed to b.p. = 36,100	
Heat of vaporization = 203,430	
Total	239,530 B.t.u.
Heat loss	61,470 B.t.u.
Thermal efficiency, run no. 1—$\frac{239{,}530 \times 100}{301{,}000}$ = 79.6%	
Run No. 2	
Heat in—88.9 cu. ft. gas at 1050 B.t.u./cu. ft.	93,350 B.t.u.
Heat out	
Heating feed to b.p. = 10,340	
Heat of vaporization = 64,000	
Total	74,340 B.t.u.
Heat loss	19,010 B.t.u.
Thermal efficiency, run no. 2—$\frac{74{,}340 \times 100}{93{,}350}$ = 79.6%	

ing only 6 to 7% acetic acid. Thus, it appears that there is an excellent possibility of economically recovering the acetic acid in the concentrated waste. This would involve acidification, extraction and/or distillation. After recovery of the acetic acid, the sodium and sulphur remaining might be recoverable, and if sulphuric acid was used for the acidification, the sodium sulphate formed would add to the value of this residue. Further investigation of this aspect is indicated.

Appendix A. Detailed Material Balances

		Solids, lb.	*Water, lb.*	*Evaporation, lb. H_2O*
	Run No. 1			
Feed	68.2 lb. at 6.3% solids	4.30	63.9	
After 30 min.	25.4 lb. at 16.9% solids	4.30	21.1	42.80
Sample 1	1.1 lb. at 16.9% solids	0.18	0.92	
	24.3 lb. at 16.9% solids	4.12	20.18	
Added	19.4 lb. at 6.3% solids	1.22	18.18	
	43.7 lb. at 12.2% solids	5.34	38.36	
After 45 min.	22.2 lb. at 24.0% solids	5.34	16.86	21.50
Sample 2	1.1 lb. at 24.0% solids	0.26	0.84	
	21.1 lb. at 24.0% solids	5.08	16.02	
Added	22.0 lb. at 6.3% solids	1.39	20.61	
	43.1 lb. at 15.0% solids	6.47	36.63	
After 60 min.	21.0 lb. at 30.8% solids	6.47	14.53	22.10
Sample 3	1.2 lb. at 30.8% solids	0.37	0.83	
	19.8 lb. at 30.8% solids	6.10	13.70	
Added	19.2 lb. at 6.3% solids	1.21	17.99	
	39.0 lb. at 18.8% solids	7.31	31.69	
After 75 min.	19.2 lb. at 38.1% solids	7.31	11.89	19.80
Sample 4	1.2 lb. at 38.1% solids	0.46	0.74	
	18.0 lb. at 38.1% solids	6.85	11.15	
Added	20.8 lb. at 6.3% solids	1.31	19.49	
	38.8 lb. at 21.1% solids	8.16	30.64	
After 85 min.	22.6 lb. at 36.2% solids	8.16	14.44	16.20
Sample 5	1.2 lb. at 36.2% solids	0.43	0.77	
	21.4 lb. at 36.2% solids	7.73	13.67	
Added	9.8 lb. at 6.3% solids	0.62	9.18	
	31.2 lb. at 26.8% solids	8.35	22.85	
After 90 min.	23.8 lb. at 35.0% solids	8.35	15.45	7.40
Sample 6	1.2 lb. at 35.0% solids	0.42	0.78	
	22.6 lb. at 35.0% solids	7.93	14.67	
Added	19.5 lb. at 6.3% solids	1.23	18.27	
	42.1 lb. at 21.8% solids	9.16	32.94	
After 105 min.	18.6 lb. at 49.3% solids	9.16	9.44	23.50
Sample 7	1.25 lb. at 49.3% solids	0.62	0.63	
	17.35 lb. at 49.3% solids	8.54	8.81	
Added	29.3 lb. at 6.3% solids	1.85	27.45	
	46.65 lb. at 22.2% solids	10.39	36.26	
After 120 min.	23.20 lb. at 44.7% solids	10.39	12.81	23.45
Sample 8	1.25 lb. at 44.7% solids	0.56	0.69	
	21.95 lb. at 44.7% solids	9.83	12.12	
Added	20.20 lb. at 6.3% solids	1.27	18.93	
	42.15 lb. at 26.3% solids	11.10	31.05	
After 135 min.	19.8 lb. at 56.0% solids	11.10	8.70	22.35
Sample 9	1.3 lb. at 56.0% solids	0.73	0.57	
	18.5 lb. at 56.0% solids	10.37	8.13	
Added	10.4 lb. at 6.3% solids	0.65	9.75	
	28.9 lb. at 38.2% solids	11.02	17.88	
After 142 min.	18.3 lb. at 60.2% solids	11.02	7.28	10.60
		Total evaporation (calculated)		209.70
	Run No. 2			
Charge	16.0 lb. at 60.2% solids	9.65	6.35	
Feed added	68.5 lb. at 6.3% solids	4.31	64.19	
	84.5 lb. at 16.5% solids	13.96	70.54	
After 44 min.	18.5 lb. at 75.4% solids	13.96	4.54	66.00

Appendix B. Detailed Heat Balances

The heat balances are calculated on the basis of the calculated material balances. Because of the lack of any data, the specific heat of the solution is assumed as 1.0 B.t.u. per lb. of feed per °F., and the heat of vaporization as 970 B.t.u. per lb. of evaporation. Although the boiling temperature varied, the sensible heat of the feed is calculated on the basis of a boiling point of 212°F. throughout. The net heat of combustion of the gas is assumed as 1050 B.t.u. per cu. ft.

Gas used, cu. ft.	*Heat in, B.t.u.*			*Heat out, B.t.u.*	*Thermal efficiency, %*
		Run No. 1			
60.6	63,600	First 30 min.			
		Sensible heat	10,300		
		Heat of vaporization	41,500	51,800	81.4
30.3	31,800	Next 15 min.			
		Sensible heat	2,930		
		Heat of vaporization	20,900	23,830	75.0
30.3	31,800	Next 15 min.			
		Sensible heat	3,320		
		Heat of vaporization	21,450	24,770	77.9
30.3	31,800	Next 15 min.			
		Sensible heat	2,900		
		Heat of vaporization	19,210	22,110	69.5
20.2	21,200	Next 10 min.			
		Sensible heat	3,140		
		Heat of vaporization	15,710	18,850	88.9
10.1	10,600	Next 5 min.			
		Sensible heat	1,480		
		Heat of vaporization	7,180	8,600	81.7
30.3	31,800	Next 15 min.			
		Sensible heat	2,990		
		Heat of vaporization	22,800	25,790	81.2
30.3	31,800	Next 15 min.			
		Sensible heat	4,420		
		Heat of vaporization	22,750	27,170	85.5
30.3	31,800	Next 15 min.			
		Sensible heat	3,050		
		Heat of vaporization	21,650	24,700	77.6
14.1	14,800	Next 7 min.			
		Sensible heat	1,570		
		Heat of vaporization	10,280	11,850	80.1
Total in	301,000		Total out	239,530	79.6
		Run No. 2			
88.9	93,350	After 44 min.			
		Sensible heat	10,340		
		Heat of vaporization	64,000	74,340	79.6

Appendix C. Equipment for Submerged Combustion Evaporation System

The following is a description of the items which would be furnished by Ozark-Mahoning Co. for the submerged combustion evaporation system already described:

Four Standardaire blowers, each to deliver 3940 c.f.m. of air to its respective burner, directly driven by 150 hp., 220/440 v., 1800 r.p.m., TEFC motors complete with motor starters and air intake cleaners and silencers.

Four Pyrometers with magnetic valves and accessories for automatic gas cut-off and alarm in the event of flame failure.

Four Foxboro Dynalog recording temperature controllers with motorized air by-pass valves to control the heat output automatically and maintain a constant temperature in each unit.

Four Foxboro Dynalog recording ratio controllers with motorized gas throttle valves to control air-gas ratio automatically throughout operating range of burner.

Four Gas pressure regulators to receive natural gas from the main at no less than 25 p.s.i.g. and assure a constant supply of gas for each burner at the proper pressure.

Four Sets of air piping connecting the blower discharges with the burners. Pipe to be of standard mild steel complete with air-gas mixing bustles and all necessary fittings and connections. Total length of each set not to exceed 40 ft.

Four Sets of gas piping connecting the gas regulators to the mixing bustles. Pipe to be of standard mild steel complete with all necessary fittings and connections. Total length of each set not to exceed 40 ft.

Four Ozark Submerged Combustion Burners fabricated of type 316 stainless steel, complete with electrical igniter and thermocouple.

Four Evaporating tanks, 12 ft. in diameter with 60° cone bottom and 45° cone top, fabricated of $^3/_8$-in. mild steel.

Four Panelboards on which are mounted the various control instruments, switches, gages, etc. for each unit.

In addition, they supply complete erection drawings and instructions on each installation and the services of a field engineer to assist in putting the equipment into operation.

The system as suggested is the most conservative setup. It is also the most flexible to take care of wide fluctuations in flow and other process variables. The capital cost may be reduced somewhat by using only two tanks with two burners each, and only one temperature controller. The use of mild steel burners instead of stainless would represent some savings. In any actual installation, these and other possible variations would be given careful study to provide the minimum investment necessary to accomplish the desired purpose.

The Ozark-Mahoning Co., of Tulsa, Okla., will make pilot plant units available, on a rental or purchase basis, to any mills desiring to do further investigation.

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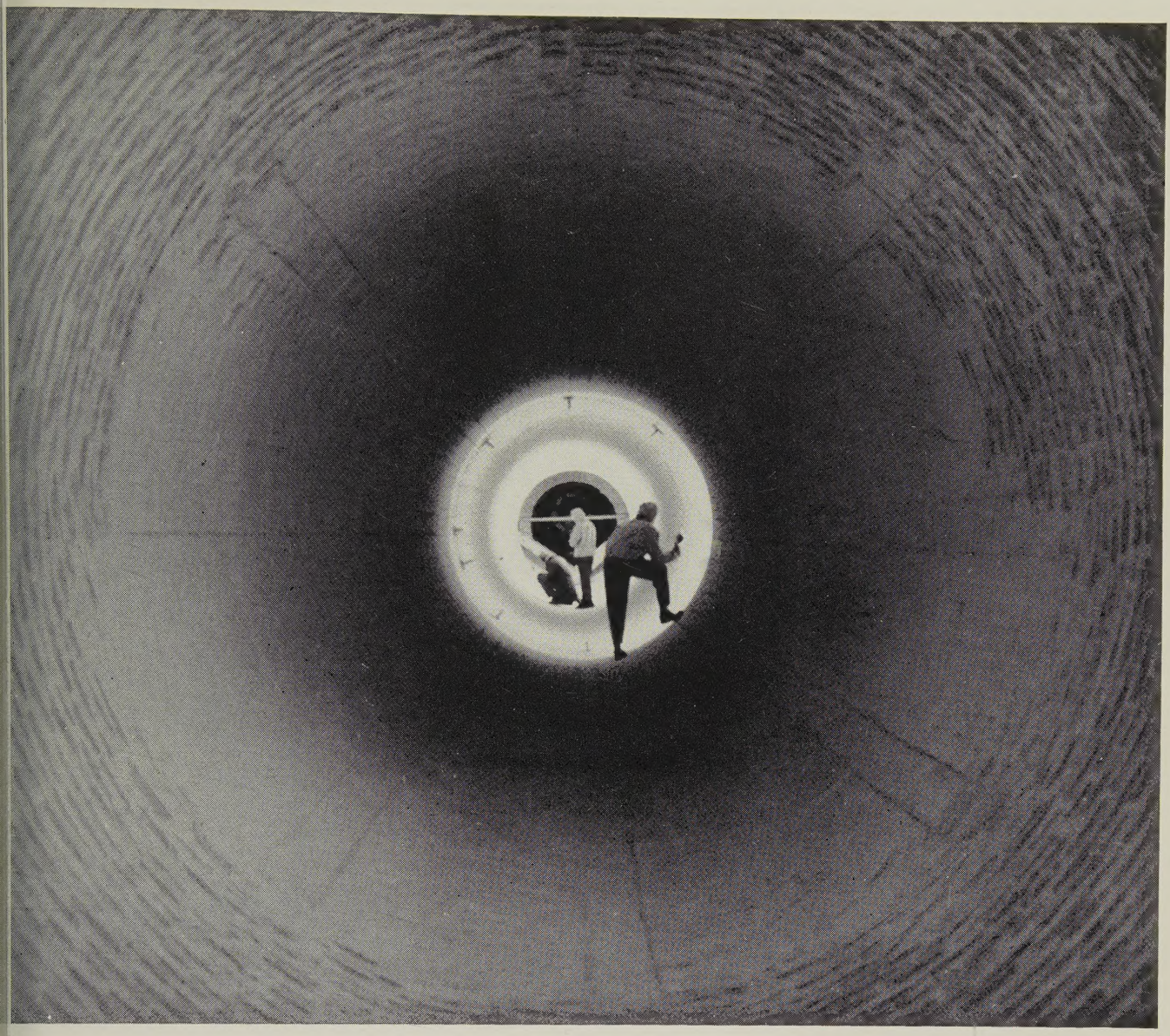

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